The access to affordable cooling challenge: managing rising demand in a warming climate with a combination of better building design and efficient air conditioning

Global emissions and energy use – residential and commercial space cooling

Emissions today	Energy use today	Energy use in 2050	
		With growing demand from higher incomes and warmer climates	*+ With better building design, improvements to existing buildings, and more efficient AC*
1 $GtCO_2$ *3% of global emissions*[1]	2,200 TWh *Of which ~100% electricity*	↑↑ 5,000 TWh *But could be higher with greater climate change*	↓ 1,200 TWh *But relies on strong policy action*

Space cooling technologies:

- Comfort in hot countries depends on two factors – temperature and humidity. Air conditioning (AC) will be by far the dominant cooling technology, but with roles also for technologies which cool the air by causing hot water to evaporate ("evaporative cooling"), for dehumidifiers in humid climates, and for fans as a low-cost (but less effective) solution.

- AC is an electric technology so decarbonising cooling is primarily a question of decarbonising wider electricity systems as rapidly as possible.

Managing rising demand for cooling with efficient AC and better building design:

- Climate change is expected to result in an additional 700 million people, or ~10% of the global population, living in hot climates by 2050.[2] Demand for cooling is projected to more than double by 2050 from 2,000 TWh-5,000 TWh due to rising incomes and warming climates.[3] If emissions do not fall fast enough to prevent even greater temperature rises, demand for cooling could be even higher.

- Despite growing access, more than 40% of people living in hot climates will not have access to cooling by 2050, either because they cannot afford it or they don't have access to electricity.[4] Expanding access to cooling is a health and equality imperative.

- The growth of demand for cooling is inevitable and should be welcomed since it will improve living standards for many low-income people living in hot climates. But this has large implications for electricity demand, and in particular for electricity required at peak times of day. This can, however, be managed in three ways:

    1. The single most effective lever to reducing electricity needs for cooling is to ensure that households purchase the most efficient AC. Currently, there is a huge difference in the average efficiency of ACs on the market both across and within countries, with significant potential for improvement.

    2. Better building design and urban planning to reduce how hot buildings get, and therefore how much air conditioning and electricity is required. Many of these can be fairly low-cost, such as painting roofs white to reflect heat and external shading by planting trees and installing window shades. In individual buildings, these "passive cooling" techniques can reduce a building's cooling energy needs by 25–40%, but the impacts can be even greater the more these can be done across entire neighbourhoods. Getting this right in new buildings is a critical opportunity; if all new builds can be built to higher standards, this could reduce annual global electricity needs for cooling in 2050 by around 20%.

1 The 1$GtCO_2$ emissions relates just to fossil fuel use to generate electricity. We estimate that an additional ~1 $GtCO_2$ of emissions relates from refrigerant leakage and venting from AC.
2 IEA (2019), *Helping a warming world to keep cool.*
3 IEA (2023), *World Energy Outlook 2023.*
4 IEA (2019), *Helping a warming world to keep cool.*

3. Consumer behaviour, such as setting thermostats at optimal levels in higher-income countries, also has a significant influence, with very major differences in the typical temperatures at which ACs are set across the world. For instance, the average Indian household with AC uses about 700 kWh per annum to achieve a typical target temperature of 24-26°C, versus a typical US household in Texas using 4,000 kWh a year, with temperature setting around 22°C.[5]

Managing emissions from refrigerants used in air conditioners and heat pumps

- ACs contain refrigerants, which contribute to global warming if they are leaked or released into the atmosphere. If leakage and release rates are not reduced, rising use of ACs could lead to 3 GtCO2e in 2050; this is equivalent to 15% of today's annual emissions from buildings.[6]
- Annual emissions in 2050 could, however, be halved with regulation to ban the use of refrigerants which have a higher global warming impact (i.e. hydrofluorocarbons), and with regulations and incentives for the proper disposal of refrigerant at end-of-life, and skills certifications to improve the quality of installations and maintenance.

Priority policy actions to tip the dial:

1. Develop clear guidance and street-by-street approaches to paint roofs white, plant trees and install other external shading across entire neighbourhoods to reduce urban heat island effects.
2. Set minimum energy performance standards for ACs and introduce labelling regulations to improve the efficiency of new ACs.
3. Implement regulations, incentives and skills accreditation schemes for the proper disposal of refrigerant from AC.

5 UE EIA (2020), *Residential Energy Consumption Survey*; Energy Informatics (2022), *Investigation on air conditioning load patterns and electricity consumption of typical residential buildings in tropical wet and dry climate in India.*
6 Systemiq analysis for the ETC. The figures are based on reasonable assumptions about how the type of refrigerant in the stock of ACs and heat pumps might change over time, and use the IEA's AC projections for 2050 and the ETC's estimates on heat pumps. Assumes an average of 10 lb refrigerant charge and a 15 year lifetime for equipment.

Cooling

3

Key messages

- Air conditioning (AC) will be by far the dominant cooling technology, but with roles also for evaporative cooling, dehumidifiers and fans.
- AC is already electrified so decarbonising cooling is primarily a question of decarbonising wider electricity systems as rapidly as possible.
- Power sector decarbonisation is critical as demand for cooling is projected to more than double by 2050 from 2,000 TWh to 5,000 TWh. This may actually be underestimating the increase in electricity requirements for cooling due to warming climates and rising incomes.
- "Passive cooling" via better building design and urban planning can reduce a building's cooling energy needs by 25–40%. Many actions to achieve this are low-cost, such as increased external shading through planting trees and painting roofs white. Getting this right in new buildings is critical; better building codes could reduce global electricity needs for cooling in 2050 by around 20%.
- The single most effective lever to reducing electricity needs for cooling is to improve the efficiency of the stock of ACs, with the market average efficiency of units sold today being far below already best available technology and with significant potential for further improvement.
- Consumer behaviour, such as setting thermostats at reasonable levels, also has a significant influence, with very major differences in typical cooling temperatures across the world.

Cooling accounts for 3% of global energy-related emissions and 6% of operational energy use – around 1 $GtCO_2$ and 2,200 TWh.[73] It is already virtually 100% electrified, meaning there is no technology transition required at energy use level. However, there are three important issues relating to the net-zero transition for cooling:

- Cooling is the fastest growing component of operational energy use, with demand growing all over the world. Exhibit 3.1 shows how cooling energy consumption is set to more than double by 2050 without strong action on energy efficiency and behaviour change. Cooled floor area today is two-thirds the size of heated floor area; by 2050, it will be 25% bigger. One key challenge is to ensure that electricity generation is decarbonised rapidly to offset this rising demand.
- Despite growing access, more than 40% of people living in hot climates will not have access to cooling by 2050, either because they cannot afford it or they don't have access to electricity [Exhibit 3.2].[74] Expanding access to cooling is a health and equality imperative. Often overlooked is the relationship between temperature and humidity; above a certain combination of heat and humidity (known as the "wet-bulb temperature"), humans are unable to regulate their temperature by sweating, creating severe risks to human health. The challenge is how to continue improving access to cooling, using a combination of air conditioning, dehumidification (where appropriate) and fans, and ensuring this is as efficient as possible.
- Air conditioning contains refrigerants which, if leaked or released into the atmosphere, contribute to global warming. This issue is explored in more detail, looking across both AC and heat pumps, in Chapter 9. New refrigerant chemicals can dramatically reduce this global warming effect. In addition, it is essential to ensure that AC is installed and maintained properly, and refrigerant is properly disposed of at end-of-life.

73 The 1 $GtCO_2$ emissions relates just to fossil fuel use to generate electricity. As we explore in Chapter 9, refrigerant leakage and venting from AC also contributes to global warming and is an overlooked issue.
74 IEA (2019), *Helping a warming world to keep cool.*

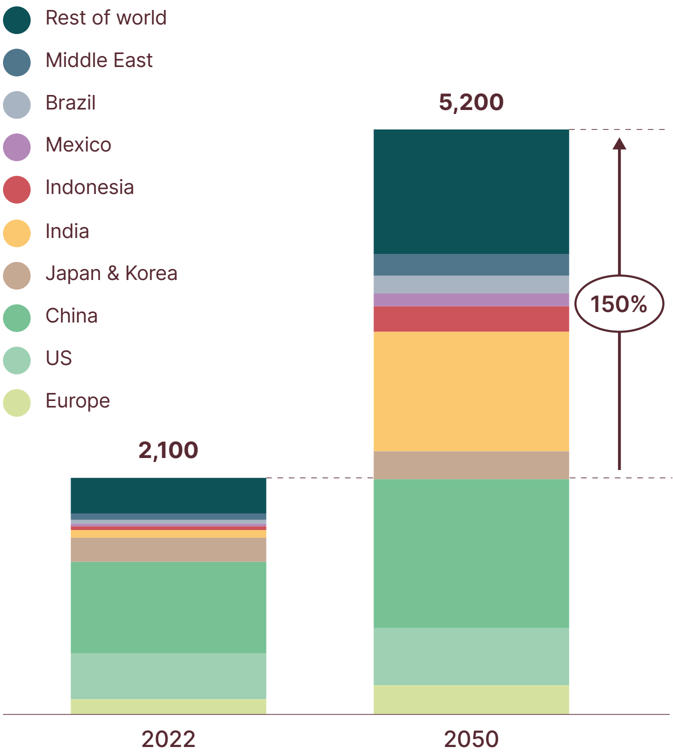
This section will cover:

- Active cooling technologies, discussing AC and evaporative cooling.
- How to manage growing demand for cooling with improvements in the energy efficiency of AC, promoting optimal consumer behaviour, and the vital importance of "passive cooling" techniques.
- Implications for the energy needed to cool buildings.

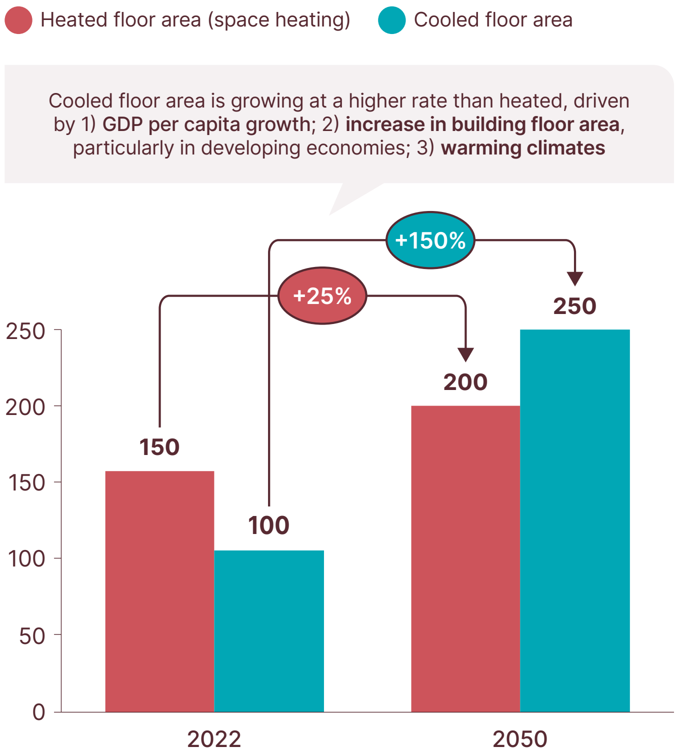
Exhibit 3.1

Cooling is the fastest growing buildings energy use, with global cooled floor area set to overtake heated floor area by 2050

Space cooling (residential + commercial) energy consumption by region, IEA baseline scenario, 2022–50
TWh



Heated floor area vs. cooled floor area (residential + commercial), IEA Net Zero scenario
Billion m^2



Rapid growth in cooling demand in countries with carbon-intensive electricity grids highlights the importance of rapidly scaling up renewables across the world.

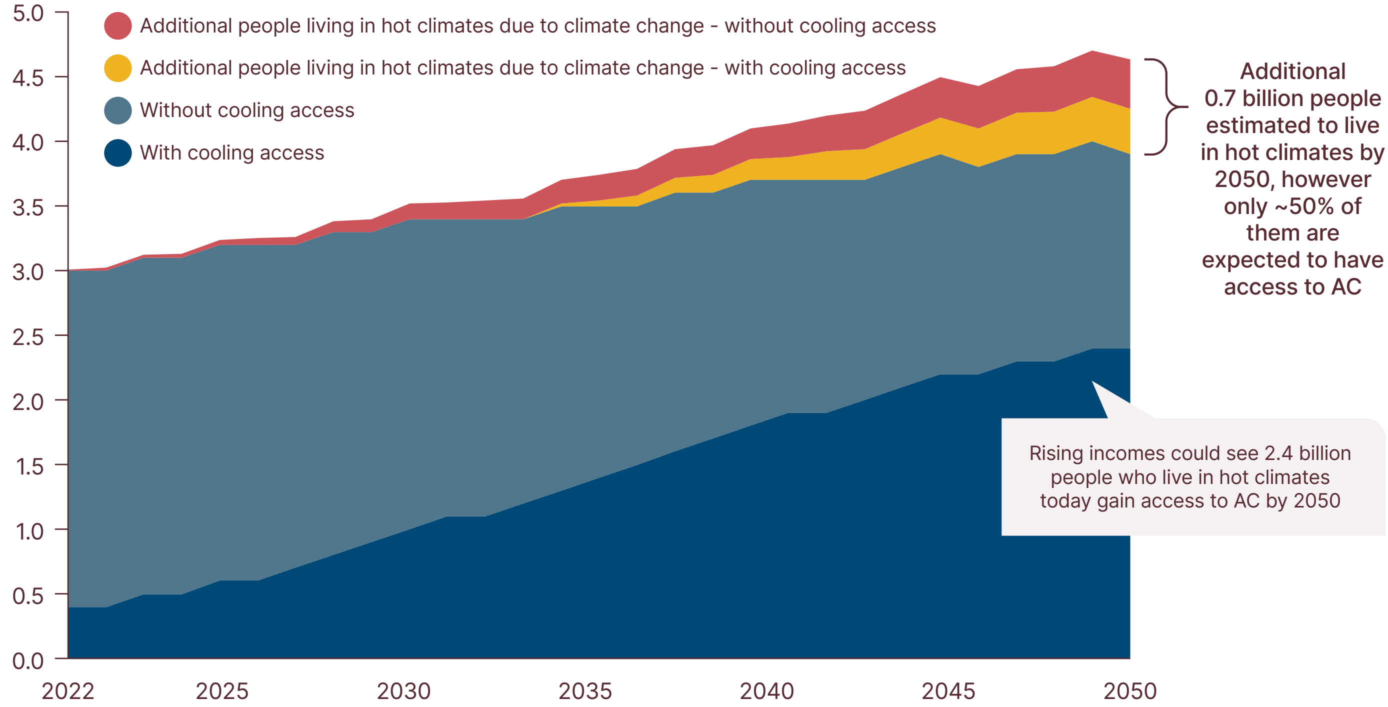
NOTE: IEA estimates of global cooling energy use in 2050 split into regions using IEA projections of AC stock in different countries in 2050.

SOURCE: Systemiq analysis for the ETC; IEA 2023; *World Energy Outlook*, https://www.iea.org/reports/world-energy-outlook-2023, re-used under license: CC BY 4.0.

Exhibit 3.2

Climate change will result in an additional 0.7 billion people needing cooling by 2050, yet more than 40% of people living in hot climates are expected to have no access to AC

Population living in hot climates with and without access to AC
Billion



NOTE: A climate is assumed to be "hot" when the sum total of the difference between the daily mean outdoor temperature and the base temperature of 10°C (cooling degree days with base temperature of 10°C) adds up to at least 5,000 over the course of one year.

SOURCE: IEA 2019; *Helping a warming world to keep cool*, https://www.iea.org/commentaries/helping-a-warming-world-to-keep-cool, re-used under license: CC BY 4.0.

3.1 Active cooling technologies: AC and evaporative cooling

The comfort provided by cooling systems depends on three effects: reducing the room temperature, reducing the humidity, and circulating the air.

There are just two main technologies which are able to lower the room temperature:

- Air conditioning: ACs move heat from inside a room and expel this outside. They work just like a refrigerator, or a heat pump in reverse. They are by far the most common cooling technology, with around two billion units in operation across residential and commercial buildings. AC can be relatively cheap, with portable units at ~$500 and typical split systems units (i.e. one outdoor and indoor unit) serving one room costing ~$1,500, but costs can increase to $2,500–5,000 for multi-split systems serving multiple rooms. Existing ACs can already achieve an efficiency rate (measured by the "coefficient of performance", or COP) of over 400%, over 4 kWh cool air can be generated for each kWh of electricity used. Reversible heat pumps which have a valve to switch the direction of flow of the refrigerant, can provide both heating (heat pump) and cooling (AC).

- Evaporative cooling forces hot air in the room through wet cooling pads, which cause the water to evaporate, absorbing heat in the process. Cold air is then circulated back into the room. Because they contribute to humidity, they are only suitable in dry climates. Evaporative coolers have many advantages – they are typically more accessible and are a cost-effective solution to AC, with portable coolers costing anywhere between $50–250. Larger and roof-mounted coolers typically cost $1,000–3000. They also have very low running costs, with a similar wattage to an electric fan. There are a few limitations, including the need for a constant supply of water and fresh air, regular maintenance, and are less effective at air filtering.

Where these space cooling technologies are unaffordable, there are a number of cooling appliances that can help people to deal with the impacts of hot climates, including humidity:

- Electric fans are a very cheap (anything from $10–100) solution that cost very little to run (wattage is around 30x lower than an AC). There are currently double the number of fans than ACs in operation today.[75] By 2050, however, there could be a similar number of fans and ACs in operation in residential buildings (around 3.5–4 billion units each). Electric fans inevitably increase room temperatures slightly (since some electrical energy input is converted to heat), but this very small effect is offset by the cooling effect of air circulation on evaporation from the skin.

- Dehumidifiers are a solution in humid climates to remove excess moisture from the air, either using absorbent material to extract water from the air, or condensing water over cold coils. Costs vary across countries and based on size, but can be as cheap as $50–100, or upwards to $500. Dehumidifiers, like fans, will increase room temperature slightly as they produce hot air to operate; however, the benefits of lower humidity in humid climates has a bigger effect on comfort.

From an energy demand perspective, the extent to which demand for AC increases is the most important question.

3.2 Managing growing demand for cooling

45% of the global population live in hot climates requiring cooling and a further 50% require cooling intermittently, for example in certain seasons.[76] However, these proportions differ hugely across regions. Despite cooling being required in virtually all parts of the world at some points in a year, it only accounts for 6% of operational energy use. This is partly because air conditioning is so efficient, but also because a significant share of cooling needs are unmet [Exhibit 3.2]. For example, despite 55% of its population living in hot climates, Africa only accounts for less than 5% of global cooling energy demand. This compares to North America accounting for 30%, from just 10% of their population living in hot climates.[77]

The IEA expects the global stock of air conditioners to increase from around 2 billion today, to 5–6 billion by 2050; the residential sector accounts for around 70% of this.[78] There are three main drivers:

- **GDP per capita:** AC ownership tends to be much higher in richer countries, for example 80% of households have an AC in North America compared to around 5% of households in Africa. As incomes increase, an additional 2.4 billion people living in hot climates could gain access to AC by 2050 [Exhibit 3.2].[79]

- **Floor area growth:** Floor area in hot climates is set to expand by 150% by 2050, from 100 billion m² to 250 billion m² [Exhibit 3.1], driven by population growth and urbanisation.

- **Warming climates:** Climate change could result in an additional 0.7 billion people living in hot climates over the next 25 years [Exhibit 3.2].[80] For those already living in hot climates, it will exacerbate cooling needs, requiring ACs to be run for longer and increasing the differential between inside and outside temperature, which reduces the COP.

Without action on energy efficiency and behaviour change (explored in the following sections), cooling energy demand could increase from 2,200 TWh today, to over 5,000 TWh by 2050.[81] Cooling demand could be 15–20% of forecasted electricity supply in Indonesia and India – a huge increase from 5–10% today.[82]

75 IEA (2018), *The Future of Cooling*.
76 IEA (2002), *Share of population living in a hot climate*, available at: www.iea.org/data-and-statistics/charts/share-of-population-living-in-a-hot-climate-2022-and-penetration-of-air-conditioners-2000-2022. [Accessed 03/10/2024].
77 IEA (2020), *Is cooling the future of heating?*
78 IEA, Space Cooling, available at www.iea.org/energy-system/buildings/space-cooling. [Accessed 24/09/2024].
79 IEA (2019), *Helping a Warming World to Keep Cool*.
80 Ibid.
81 IEA (2023), *World Energy Outlook 2023*.
82 Systemiq analysis for the ETC; IEA (2023), *World Energy Outlook 2023*; BNEF (2023), *New Energy Outlook 2022*.

It is possible that cooling energy needs will increase more than current projections suggest, with three key uncertainties:

- The pace and extent to which emissions are reduced globally, and the implications for warming climates.
- The feedback loop between AC use and higher outdoor temperatures. Estimates suggest that waste heat emitted from ACs could increase the mean air temperature by more than 1°C in urban locations in the evening.[83] This could exacerbate "urban heat island effects" which result from dense concentrations of concrete and buildings which absorb and retain heat. This could drive even greater use of AC and have severe consequences for homeless people, or households which cannot afford AC.
- Around 40% of heat pump sales over the coming decades could be reversible ones which can provide heating and cooling.[84] This could drive additional cooling demand than would otherwise have occurred, for example, in parts of Europe where cooling needs may not warrant purchasing a separate air conditioner, but where households which have installed heat pumps to provide heating will then decide to use AC in summer as well.

It is, however, possible to limit the increase in energy demand for cooling without impacting living standards (i.e. without reducing the extent to which cooling needs are met). This section outlines the opportunities to:

- Increase the efficiency of air conditioning.
- Optimal consumer behaviour.
- Reduce cooling needs through passive cooling techniques in buildings.

3.2.1 Opportunities to improve energy efficiency

Just like a heat pump, ACs are able to produce more useful output for the electricity put in. Similarly, their efficiency is determined by the temperature differential between the source and sink; because the required temperature differential for ACs tends to be lower than for heat pumps (e.g., going from 35°C to 25°C, compared to going from 0°C to 20°C), air conditioners on the market today can often achieve efficiencies of 400–800%, compared to around 300–400% for heat pumps.[85]

There is a huge variation in the efficiency of ACs on the market today, both within and across countries, meaning there is significant potential to realise efficiency gains just through better policies such as minimum efficiency standards and labelling [Exhibit 3.3]:

- In Europe and the US, the market average efficiency is around 2–3 times lower than the best available technology.
- In other high-income countries such as Canada and Australia, both market average and best available efficiencies are much lower than in Europe and the US.
- The key challenge is countries with weaker regulatory capacity but very high cooling needs, such as India and Thailand where average efficiencies are low.

In the US and EU, Minimum Energy Performance Standards (MEPS) and labels have helped more than halve AC energy consumption since policies were introduced.[86] In China, a tightening of minimum energy performance standards in 2019 saw the most efficient ACs growing their market share from 20% to 55% in two years.[87] The key question is whether there is a cost premium to purchasing a more efficient AC:

- In some countries, such as Vietnam, there is a clear price premium to more efficient AC. This means minimum energy performance standards are key, even if they increase cost.
- In some countries, such as Thailand, an AC with an efficiency of over 600% can cost the same as one with an efficiency of less than 400%. This means better energy labelling, in addition to MEPS, are key.[88]

83 Salamanca, et al. (2014), *Anthropogenic heating of the urban environment due to AC.*
84 IEA (2018), *The Future of Cooling.*
85 Ibid.
86 Ibid.
87 CLASP (2023), *China's MEPS Lead to Major AC Market Transformation.*
88 IEA (2023), *Keeping cooling in a hotter world.*

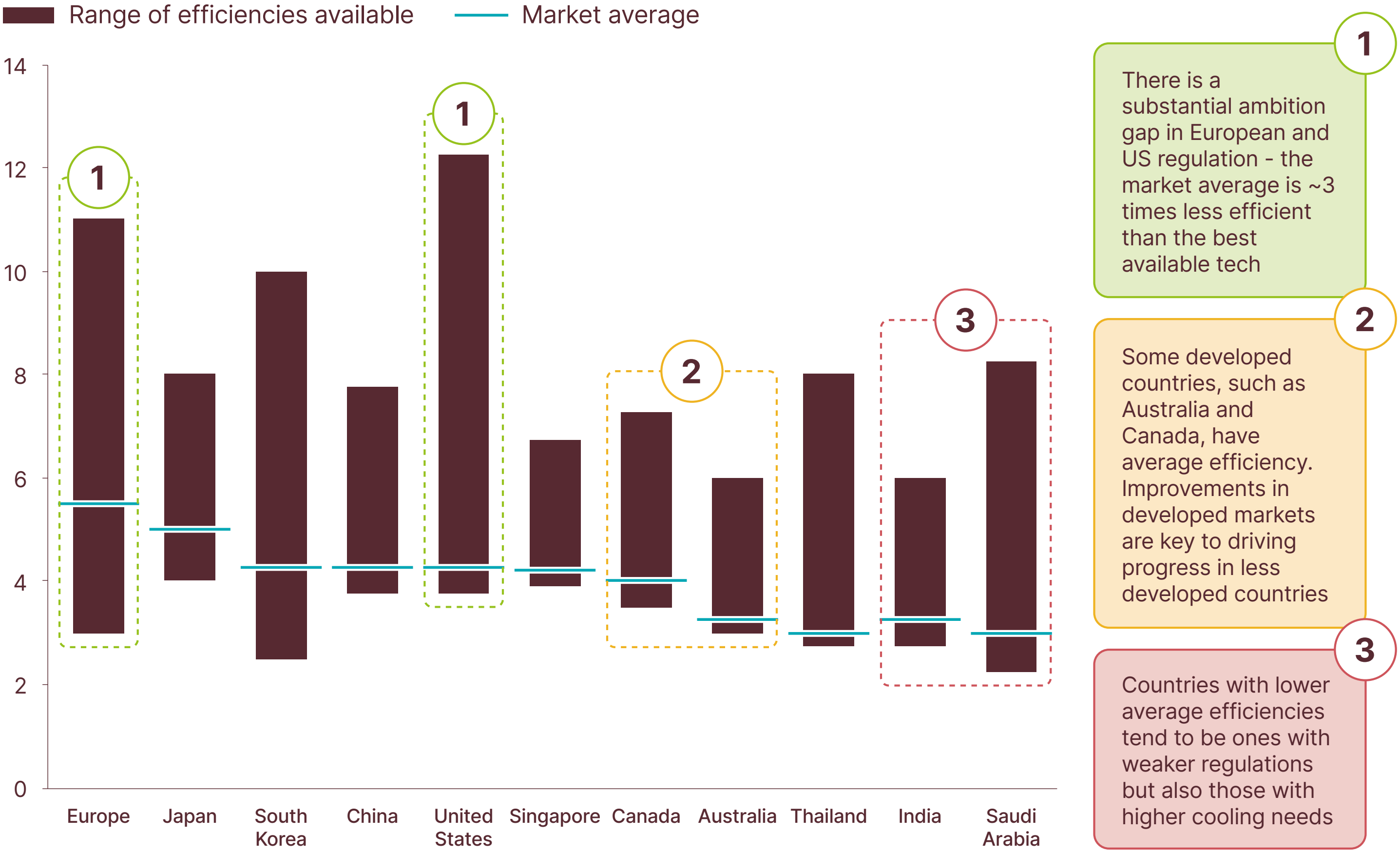
In addition, continued technological advancements will drive further improvements. Key opportunities include variable speed motors which allow an AC to scale up and down (rather than just on and off), and a transition to refrigerants which are able to transfer more heat for the same electrical input (see Chapter 9).

Driving up the average efficiency of the AC stock is the single most effective solution to reducing the cooling energy demand challenge. For example, if average AC efficiency was able to reach 700%, annual electricity requirements for cooling in 2050 could be 70% lower in India, 40% lower in China and 50% lower in the US, compared to holding current efficiencies constant. The impact on global total electricity demand could be savings of 500–1,000 TWh per year.

Exhibit 3.3

There is a huge opportunity to increase the efficiency of ACs on the market, with the best available technology typically twice as efficient as the market average

Seasonal energy efficiency ratio (SEER) of market available residential AC units in selected regions, 2018
Watt of cooling output per watt of energy input



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

NOTE: SEER is calculated by cooling output divided by energy input over a typical cooling season.

SOURCE: IEA 2018; *The Future of Cooling*, https://www.iea.org/reports/the-future-of-cooling, re-used under license: CC BY 4.0.

3.2.2 Promoting optimal consumer behaviour

Currently, there are huge differences in annual household energy consumption for cooling across countries. Though, in many instances, cooling is essential to human health, especially to deal with humidity, it is often used excessively, particularly in high-income countries:[89]

- In Texas, US, 95% of households own an AC, with average annual energy consumption of 4,000 kWh. Thermostats are typically set very low (~22°C) and are often left on all day.

- In Guangzhou, China and Hyderabad, India, 75–85% of households own an AC, with average annual energy consumption of ~700 kWh. Thermostats are typically set at around 24–26°C and are used for around five hours a day.

In richer countries such as the US and parts of the Middle East, perverse heating and cooling behaviours persist where thermostats in the summer are set lower than thermostats in the winter.[90] This suggests cooling energy consumption far above true need.

There is a risk that, as incomes grow in lower-income countries such as India, AC consumption could begin to exceed need. To illustrate the importance of avoiding such an adverse behaviour change, our analysis suggests that if households in India used their AC as much as those in Texas, electricity requirements for cooling could be six times higher in 2050, from ~400 TWh to 2,700 TWh.

Policy can play a key role in encouraging or mandating behaviour change:

- **Temperature limits in buildings:** In Belgium, public buildings have a heating limit of 19°C and an AC limit of 27°C.[91] Beijing's "energy-saving police" check that AC in commercial buildings (e.g., offices, hotels, malls) is not set below 26°C. In India, the government mandated that all AC must have a default temperature no less than 24°C.[92]

- **Penalties:** Italy introduced fines of €500–3,000 for industrial buildings that set space cooling temperatures below 25°C.

- **Encouragement:** The Japanese "Cool Biz" (cool to 28°C) and "Warm Biz" (heat to 20°C) programmes gave social permission for professionals to adopt dress codes that match varying office temperatures.

89 UE EIA (2020), *Residential Energy Consumption Survey*; Odyssee-mure (2023), *Sectoral profile – households*; Lawrence Berkeley National Laboratory (2004), *A Tale of Five Cities: The China Residential Energy Consumption Survey*; Guo et al. (2022), *Extreme temperatures and residential electricity consumption: Evidence from Chinese households*; Energy Informatics (2022), *Investigation on air conditioning load patterns and electricity consumption of typical residential buildings in tropical wet and dry climate in India*.
90 National Renewable Energy Laboratory (2017), *Residential Indoor Temperature Study*.
91 The IEA's Net Zero Scenario assumes a temperature limit of 24°C on AC.
92 Ministry of Power, *BEE Notifies New Energy Performance Standards for Air Conditioners*, available at www.pib.gov.in/PressReleasePage.aspx?PRID=1598508. [Accessed 24/10/2024].

3.2.3 The vital importance of "passive cooling" techniques

Just as with heating, there are many passive cooling techniques that can reduce the need for active cooling. The health and wellbeing imperative of passive cooling is huge, especially for households which are unable to afford AC.

Passive cooling focuses on minimising heat gain and maximising natural ventilation:

- **Orientation** of a building's longest sides against the direction of the sun to minimise solar gain, balanced against the need for solar gain for winter comfort.
- **Material and colour choice:** Painting roofs and walls white to reduce how much heat is absorbed, using bright and reflective coatings to reflect sunlight and reduce solar gain, and using ceramics and tiles which have a high thermal resistance.
- **Building envelope and design:** A low window-to-wall ratio (as windows lead to more solar gain) or using low-emissivity windows which let in light but reflect heat, and using shading structures such as awnings, trellises and porticos. Optimising for natural ventilation is also key, including vents, solar chimneys, and optimising building shape to maximise natural airflow.

Differences in climate will require different techniques:

- In humid climates, ventilation is key. This means high ceilings and many openings for constant air flow, allowing warm air to drift to the ceiling.
- In dry climates, with huge differences between day and night temperatures, heavy exterior walls and roofs can help keep the temperature constant for longer, creating a natural barrier between inside and outside temperatures.

The huge opportunity for passive cooling in new buildings

Passive cooling techniques could in principle reduce cooling energy needs by 25–40%, with reductions of even 75% achievable if optimal building design was combined with best possible urban design [Exhibit 3.4]. It is, however, much harder to assess the realistically achievable reduction given implementation costs and barriers, with huge variation depending on climate, labour and material costs, and the extent of technique deployed (e.g., external shading can range from trees and retractable awnings to concrete structures).

What is clear, is that many of these choices are low cost, low effort and can have a very big impact on how hot a building gets. For example, in one case study, painting the roof of a factory in Indonesia white led to a 10°C reduction in indoor temperatures.[93]

Seizing this low cost potential is, however, often held back by a lack of knowhow and awareness among developers, weak regulation, and by the fact that the benefits of passive cooling techniques will accrue to households or commercial building users, not to the property developers making decisions on building design.

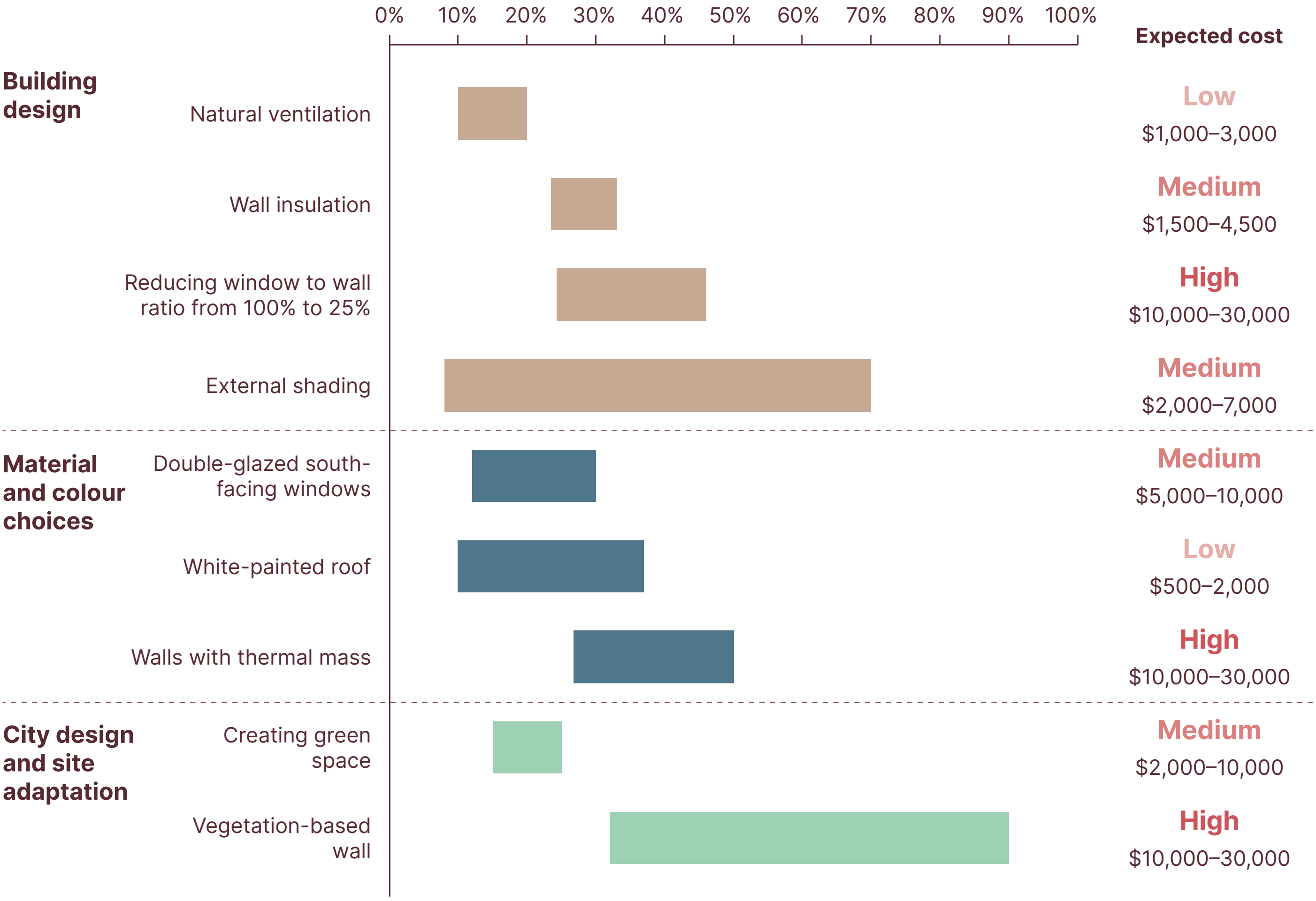
In addition, it can be challenging to make an economic case for investing in passive cooling in lower income households. Exhibit 3.5 shows that AC use and energy bills are typically lower in lower-income countries, compared to the US and Europe, meaning the financial returns to any retrofitting investment will be lower. However, the health and social imperatives are huge. This highlights the critical importance of more ambitious building codes (see Chapter 8) and training and awareness of developers of low-hanging fruit opportunities.

93 Cool Coalition (2023), *Indonesia's Cool Roofs Champion.*

Exhibit 3.4

Passive techniques can reduce cooling energy consumption in buildings by 25–40% on average and many of these are very low-cost, such as painting roofs white and planting trees

Impact on annual cooling energy consumption of passive cooling techniques
%



The cost and impact of passive cooling techniques varies massively depending on:

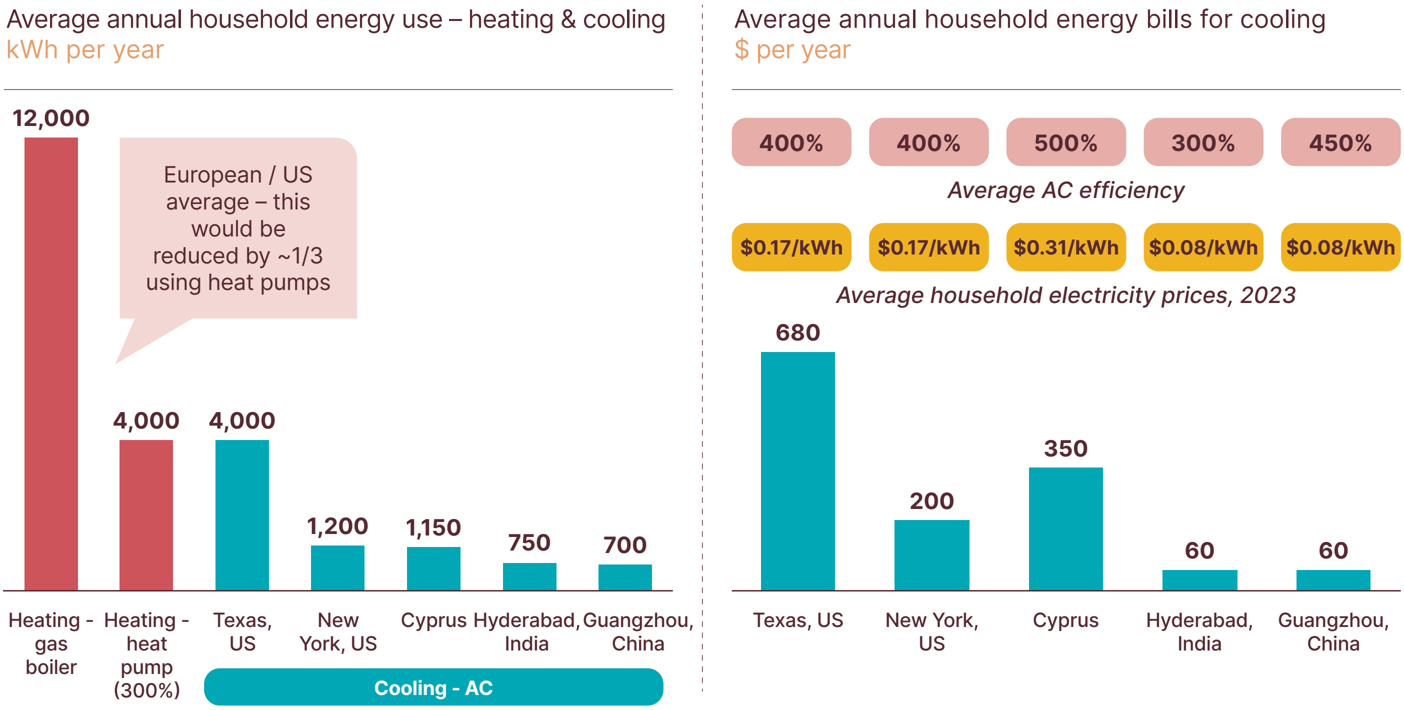
1. Climate.
2. Labour and material costs in different countries.
3. Extent of technique deployed (e.g., external shading can range from trees and retractable awnings to concrete structures).

NOTE: IRR analysis assumes a discount rate of 5% over 50 years. Based on an average single-family flat/house of 60–80 m².

SOURCE: Systemiq analysis for the ETC; Ahmed et al. (2023), *The impact of window orientation, glazing, and window-to-wall ratio on the heating and cooling energy of an office building: The case of hot and semi-arid climate*; Song et al. (2021), *A review on conventional passive cooling methods applicable to arid and warm climates considering economic cost and efficiency analysis in resource-based cities.*

Exhibit 3.5

Household energy bills for cooling are generally smaller than heating, meaning households will be less likely to invest in retrofitting without government policy and incentives



SOURCE: Systemiq analysis for the ETC; Thunder Said Energy (2022), *Air Conditioning: Energy Consumption?*; Statista (2023), *Household electricity prices 2023*; US EIA (2020), *Residential Energy Consumption Survey*; Odyssee-mure (2023), *Sectoral profile – households*; Florides et. Al (2000), *Modelling of the modern houses of Cyprus and energy consumption analysis*; Lawrence Berkeley National Laboratory (2004), *A Tale of Five Cities: The China Residential Energy Consumption Survey*; Guo et al. (2022), *Extreme temperatures and residential electricity consumption: Evidence from Chinese households*; Energy Informatics (2022), *Investigation on air conditioning load patterns and electricity consumption of typical residential buildings in tropical wet and dry climate in India*; IEA (2018), *The Future of Cooling*.

The other crucial aspect with new builds is to consider how better urban design can reduce heat island effects. In humid climates, large distances between buildings is important for air circulation; in dry climates, dense and narrow streets can help provide shade. Simple things such as planting trees along streets and preserving nature can have a huge impact on creating cooler streets and wellbeing.

The potential to retrofit buildings for passive cooling

Many of the passive cooling techniques discussed above can be fairly easily applied to existing buildings, for example, painting roofs white, adding trees for shading, and some forms of insulation [Box I]. Other techniques such as redesigning for natural ventilation or selecting materials which do not absorb heat are much harder to retrofit. This highlights the importance of getting it right at the point the building is constructed, with better building codes (see Chapter 8).

Another challenge is that household energy bills for cooling are generally lower than typical heating bills, meaning passive cooling methods are not necessarily cost-effective. With key exceptions in rich, hot regions such as Texas – where AC energy use is as high as typical heating energy use in Europe and the US – annual kWh consumed for cooling in middle-income countries are around a quarter of the typical electricity input to provide residential heat via a heat pump. As set out in Section 2.2.4, this reflects differences in household income, use and thermostat settings. It might also reflect the fact that the temperature differential required in colder countries (e.g., going from 0°C to 20°C) is higher than in hot countries (e.g., going from 35°C to 25°C).

Combined with often lower electricity prices in lower-income countries, AC energy bills in some parts of India and China could be less than $100 per year. While this may be a relatively high share of annual disposable income for some households, it makes the economic paybacks to investing in retrofitting challenging. This highlights the importance of policies and the provision of low-cost finance to ensure households can reap the health and comfort benefits of passive cooling.

Box I **Cool roofs in India**

Cool roofs are one of the simplest and cost-effective ways to reduce heat in buildings by reflecting sunlight with highly reflective white paint. They can lower indoor temperatures by around 2–4.5°C and if combined with tree planting in city-wide applications can reduce the ambient temperatures by around 2°C.[94]

Following in the footsteps of New York, Los Angeles and Toronto, the city of Hyderabad, India, launched a cool roofs programme, targeting 300 million m² of cool roof area by 2028. Key policies include:

- Mandatory cool roofing in all public buildings, commercial buildings and residential buildings over 500 m².
- Government rollout of cool roofing in all social housing.
- Outreach and awareness programme, including demonstrations, city-wide advertisement boards, and volunteering programmes to coat rooftops.

Other cool roof community programmes have been run in Jodhpur, Bhopal, Surat, and Ahmedabad targeting low-income communities living in slums, which often have roofs made of heat-trapping materials, such as tin sheets, cement sheet, plastic and tarpaulin without sufficient ventilation.[95] Cool roofs can lower indoor temperatures by up to 5°C in these buildings.

94 Government of Telangana (2023), *Telangana Cool Roof Policy 2023-28.*
95 NDRC, *Cool Roofs: Community-led initiatives in four Indian cities*, available at https://www.nrdc.org/bio/anjali-jaiswal/cool-roofs-community-led-initiatives-four-indian-cities [Accessed 24/10/2024].

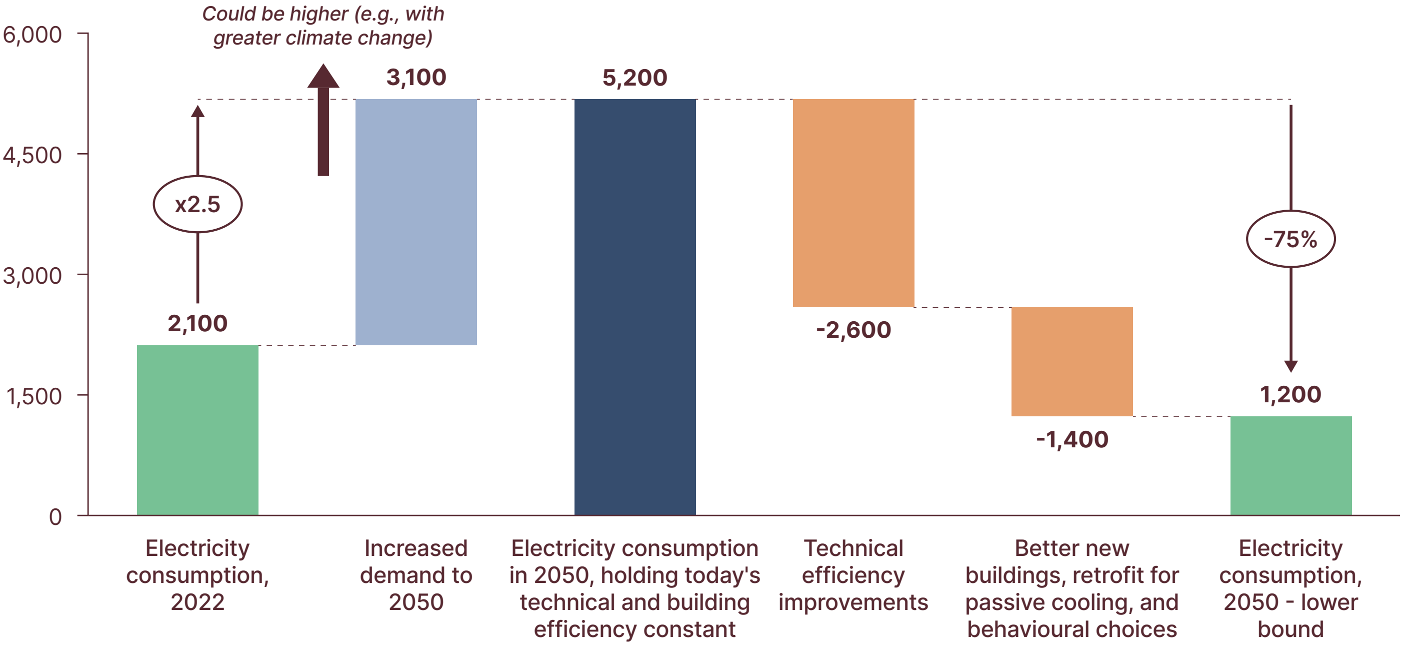
3.3 Implications for the energy needed to cool buildings

Rising demand could see electricity demand from cooling increase 2.5 fold by 2050, from 2,100 TWh to over 5,000 TWh. However, in principle this could be more than offset by energy efficiency improvements to air conditioners and by the application of passive cooling techniques to new and existing buildings. Indeed Exhibit 3.6 shows that electricity consumption from cooling could be lower than it is today, at 1,200 TWh.[96] The crucial issue is how much of this very large technical potential can in practice be achieved.

Exhibit 3.6

Improving the technical efficiency of AC and deploying passive cooling techniques in new buildings could more than offset the increase in electricity demand - but relies on strong policies

Global electricity consumption from cooling, 2020 to 2050
Annual TWh



SOURCE: Systemiq analysis for the ETC; IEA (2021), *Net Zero by 2050*.

96 Note that this shows global totals for residential and commercial buildings (see Chapter 7 for further discussion on commercial buildings).