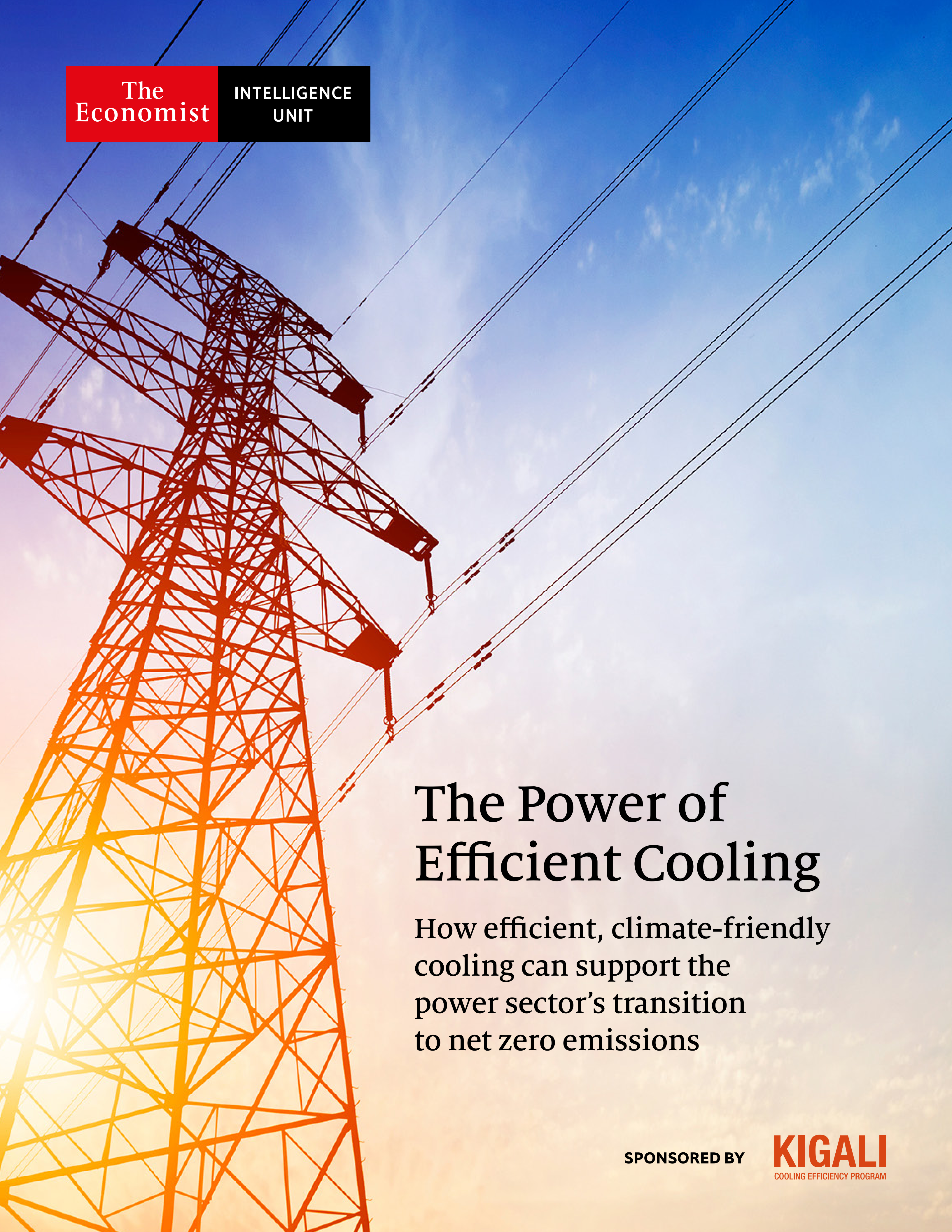

The Economist Intelligence Unit

The Power of Efficient Cooling

How efficient, climate-friendly cooling can support the power sector's transition to net zero emissions

SPONSORED BY KIGALI COOLING EFFICIENCY PROGRAM

Contents

Foreword

The Power of Efficient Cooling is an Economist Intelligence Unit (EIU) report that has been commissioned by the Kigali Cooling Efficiency Program (K-CEP). The findings are based on an extensive literature review, an expert interview programme, and econometric modelling conducted by The EIU between July and October 2020. The EIU bears sole responsibility for the content of this report. The findings and views expressed do not necessarily reflect the views of K-CEP.

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The Economist Intelligence Unit (EIU) is the research arm of The Economist Group, publisher of *The Economist*. As the world's leading provider of country intelligence, it helps governments, institutions and businesses by providing timely, reliable and impartial analysis of economic and development strategies. Through its public policy practice, The EIU provides evidence-based research for policymakers and stakeholders seeking measurable outcomes, in fields ranging from gender and finance to energy and technology. It conducts research through interviews, regulatory analysis, quantitative modelling and forecasting, and displays the results via interactive data visualisation tools. Through a global network of more than 650 analysts and contributors, The EIU continuously assesses and forecasts political, economic and business conditions in more than 200 countries. For more information, visit www.eiu.com.

About the Kigali Cooling Efficiency Program (K-CEP)

The Kigali Cooling Efficiency Program (K-CEP) is a philanthropic collaboration launched in 2017 to support the Kigali Amendment to the Montreal Protocol and the transition to efficient, climate-friendly cooling solutions for all. K-CEP works in over 50 countries in support of ambitious action by governments, businesses and civil society. K-CEP's programme office, the Efficiency Cooling Office, is housed at the ClimateWorks Foundation in San Francisco.

Introduction

The role of the power sector is to provide access to reliable, secure and affordable electricity to people whenever they need it. Due to the increasingly urgent climate crisis, the Intergovernmental Panel on Climate Change (IPCC) has called on the power sector to continue providing this service while also cutting emissions.[1] In 2018, the IPCC announced that, in order to limit global warming to 1.5°C, global net human-caused emissions of CO_2 would need to fall by about 45% from 2010 levels by 2030, and reach "net zero" by around 2050.[2] In practice, this means that all sectors must shift away from fossil fuels to reduce emissions, while removing CO_2 from the atmosphere to offset any remaining emissions.[3,4,5,6]

Rising demand for electricity is driven by various uses including space cooling which – particularly at certain times of the day – threatens the power sector's ability to deliver secure, affordable and net zero power. This report is based on an extensive modelling exercise that identifies the financial and environmental costs of energy supply if electricity demand from space cooling is not reduced.[7] It quantifies how these costs would be reduced if space cooling were made more efficient, and explores other solutions that the power sector could consider, including demand response programmes and thermal energy storage. Finally, the report highlights why it is in the interest of the power sector, policymakers and consumers to pay attention to cooling efficiency, and outlines priority actions that need to be taken to ensure that the contribution of efficient cooling to speeding up and reducing the cost of the race to net zero can be realised.

Key findings

- Electricity demand for cooling is expected to grow almost twofold at an average annual rate of 6.1% to 2030. Expanding capacity to meet this demand will cost US$4.6trn over the next ten years and contribute 10.1 $GtCO_2$ emissions.[8]
- Of the $4.6trn, more than half (54%) of the costs are from generating and operating power plants to meet demand at peak hours.[9]
- Even if stakeholders embrace a shift to renewables, the financial and environmental costs – $4.5trn and 9.2 $GtCO_2$ – will still be high.
- Focusing on more efficient cooling can substantially reduce these costs:
  - Installing more efficient air conditioning equipment could save $0.9trn and 2.0 GtCO2 by 2030.
  - Reducing the need for air conditioning units could increase those savings to $3.5trn and 7.6 GtCO2 over the same time period.
- Without the implementation of sustainable cooling solutions, countries aiming to meet net zero emissions in 2050 are likely to miss those targets by up to eight years.
- Efficient cooling can expedite the transition to net zero at a lower cost, as well as providing benefits for all stakeholders, including governments, consumers and the power sector itself, given the right incentives.

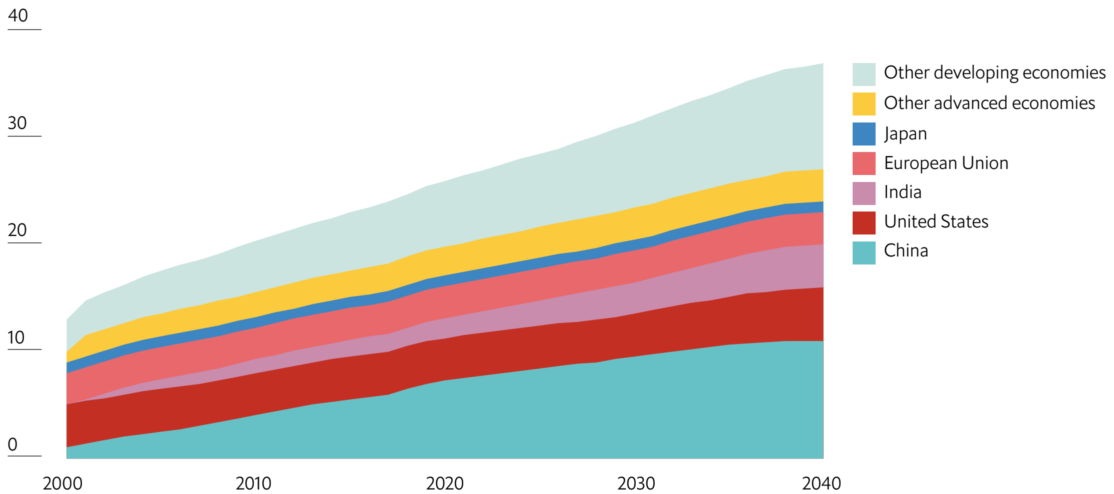
The need for *secure* and *reliable* electricity

Electricity is an integral part of our lives, used to power everything from cars to computers. The International Energy Agency (IEA) forecasts global electricity demand to grow by 2.1% each year out to 2030,[10] driven by rising household incomes, electrification of transport and increasing demand for digitally connected devices and air conditioning (AC). Growth will be particularly high in developing countries.[11]

The power sector needs to prepare itself to meet the new levels of electricity demand. If it fails to do so, people will be left without electricity, which can have significant impacts on health, safety and productivity.

About to surge

Global electricity demand by region (2000-2040, Thousand TWh)



Source: IEA Stated Policies Scenario[12]

Power outages damage the economy and put human health in danger

Electricity has become central to human life – it keeps fresh food cool, enables transportation systems to function, provides light and, now more than ever, enables us to stay connected to one another.[13] However, sometimes electricity provision fails us. This failure can take the form of blackouts, where we see large-scale service interruptions, or brownouts, where power providers reduce the flow of electricity to certain areas to prevent a blackout.[14] Uneven electricity supply can significantly damage economic activity: a 2019 study estimated that brownouts resulted in a 30% loss in productivity across organisations in the US.[15]

Power outages can cause major disruptions to daily life. In July 2012, 700m people in India were left without power when outages – resulting from the use of AC and other appliances, or as the power minister put it, "overdraws from the grid" – hit 20 states.[16] Trains stopped, traffic lights went out and, according to one news source, "electric crematoriums stopped operating, some with bodies left half burnt before wood was brought in to stoke the furnaces."[17]

Even just short periods of time without electricity can put human health in extreme danger. Hospitals have to quickly shift life-support equipment to backup generators. These generators may not be routinely tested and may have a lag before they kick in, potentially resulting in a period of time during which crucial life support is not provided.[18]

Power outages during periods of high temperatures[19] can leave people struggling to shelter from the heat, without AC. Yury Dvorkin, a professor at New York University's Tandon School of Engineering, told one news source following a blackout caused by rising temperatures that it could take just three to four hours before health issues arise for the most at-risk populations.[20] Power outages need to be avoided not just to prevent economic losses but to protect human health and livelihoods.

It is not just a lack of electricity that causes problems: power surges also hinder economic output by directly damaging commercial, industrial and household electronic equipment.[21]

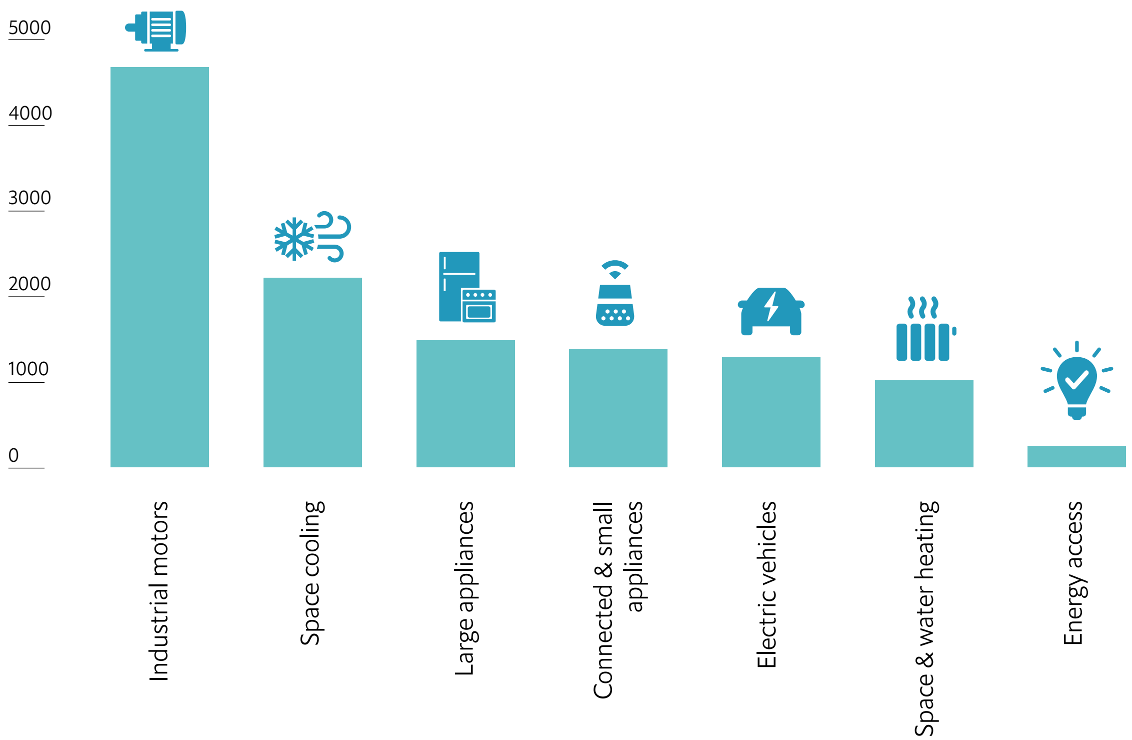
Space cooling brings a host of benefits but places a strain on the power sector

Cooling technologies – specifically, AC and refrigeration – bring benefits that are crucial to achieving the Sustainable Development Goals (SDGs).[22] Cooling is central to health and prosperity. It helps to keep food fresh and temperature-sensitive vaccines viable. Space cooling in particular – both residential and commercial AC systems, including packaged and split units, chillers, and other large space cooling systems – maintains comfort in buildings, and provides a safe, productive environment for workers and students.[23]

Space cooling is driving growth in electricity demand: it is forecast to account for the second-largest end-use of total electricity demand growth out to 2040, after industrial motors, and it accounts for more than the electricity used by electric vehicles (EVs).[24]

Charging up

Electricity demand growth by end-use (2018-2040, TWh)



Source: IEA Stated Policies Scenario [25]

Urbanisation, income growth and increasingly frequent and severe heatwaves are driving the rapid growth trend for cooling demand. In 2019, space cooling accounted for 8.5% of total electricity demand globally.[26]

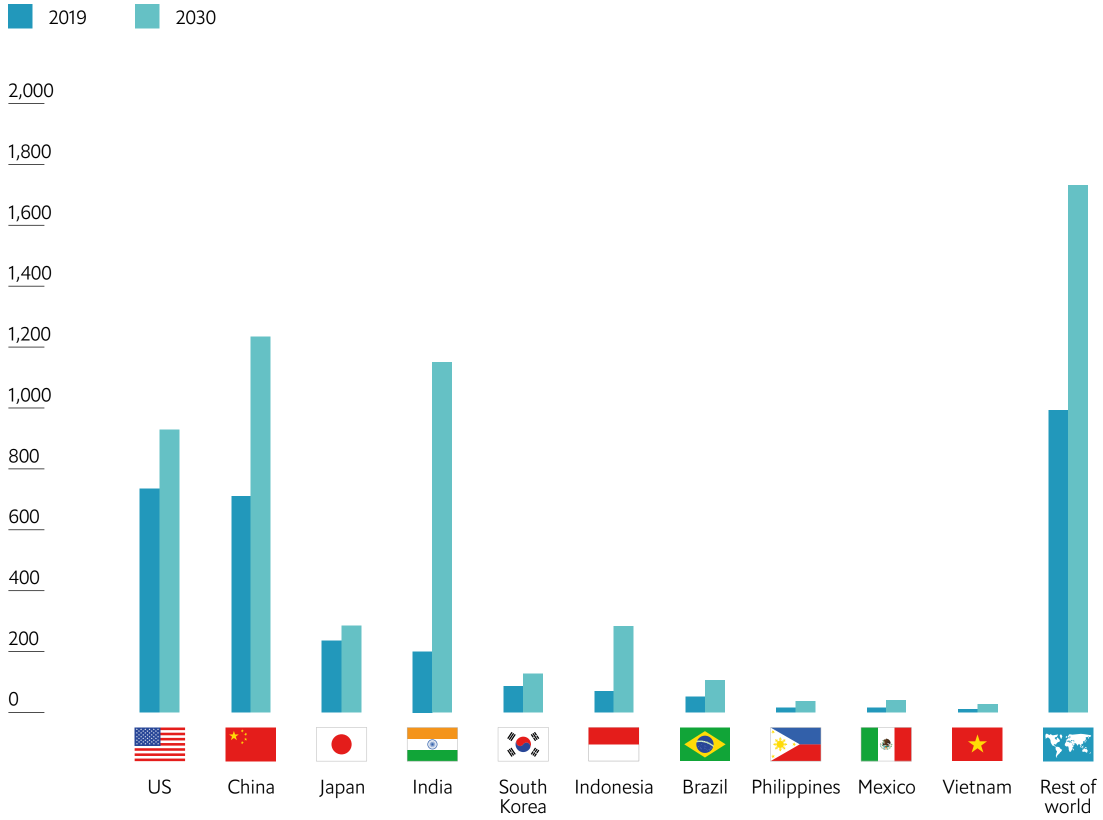
Demand is particularly high in cities that have a hot season: Delhi and Beijing currently use half of their electricity to run AC during the summer months.[27]

We estimate that, globally, total electricity demand for space cooling will grow by 6.1%[28] per year out to 2030, from 3,300 terrawatt-hours (TWh) in 2019 to 5,950 TWh.[29] India is likely to experience particularly high growth, with its share of total electricity demand for cooling expected to increase from 7% in 2020 to almost 20% in 2030 based on EIU analysis.

Despite this rapid growth trajectory, energy use from cooling is often underestimated. According to Toby Peters, Professor in the Cold Economy at Birmingham University, "Most people tend to think of energy services in terms of heat and light and transport."[31] However, research by the Netherlands Environmental Assessment Agency suggests that, by 2060, energy used in cooling will overtake energy used in heating.[32,33] This will come as no surprise in countries like Saudi Arabia, where temperatures can reach over 50°C in the summer months, and where families typically live in relatively large villas with multiple AC units.[34,35] One study estimates that 73% of people in the Kingdom use AC between 10 and 24 hours a day throughout the year, with most people leaving it on non-stop from May through to September due to the extremely hot conditions.[36]

New levels of cool

Electricity demand for space cooling by country/regions (2019 and 2030, TWh)



Source: EIU analysis based on multiple sources[30]

COVID-19 and cooling demand

As countries went into lockdown and businesses and industrial sites closed, electricity demand fell to levels typically seen on Sundays.[37] However, in some places, electricity demand did not fall as much as might be expected. In Delhi, for instance, overall electricity demand was not significantly affected due to heat stress and residential AC demand.[38,39] In New York, rising demand for residential AC triggered warnings of increased risk of blackouts, as residential grids were not designed for people being at home 24 hours a day.[40] In California, demand for AC increased by 9% compared with 2019.[41]

If electricity demand growth from space cooling is not restrained, or electricity supply is not expanded, we will see an increasing number of power outages, and consequent economic and health costs. As recently as August 2020, there were power outages throughout California as the grid became overwhelmed by energy demands during a heatwave. The power operator had to declare a statewide state of emergency for the first time since 2001.[42]

"Cooling for All" is still far from a reality

Even if the level of cooling demand outlined in the forecasts is met, Cooling for All – an aim set out by, among others, Sustainable Energy for All, focusing on ensuring access to affordable and sustainable cooling solutions for the vulnerable – will not be met.[43] Across 54 countries, more than 1bn people among the rural and urban poor are at high risk due to their lack of access to electricity and their below-poverty-line incomes which prevent them from accessing sustainable cooling. Lack of access to controlled cold chains means that food spoils without proper refrigeration and vaccines are exposed to high temperatures.[44]

Losing your cool: Managing peak demand

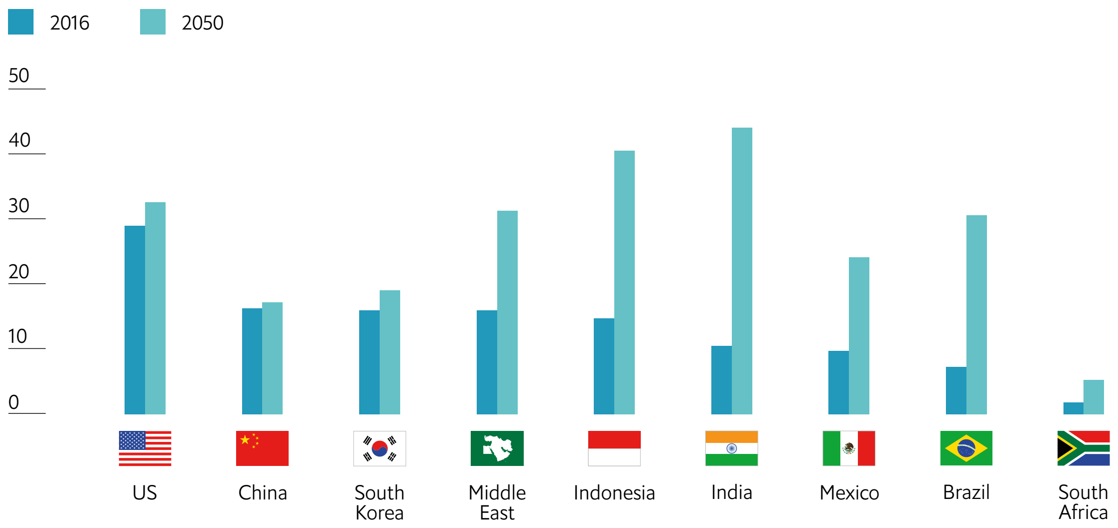
Demand for electricity is not constant throughout the day. People often demand electricity at the same time, and power providers have to meet surges in demand at a moment's notice. The term "peak demand" is used to describe "the times of day when our electricity consumption is at its highest". This is often in summer months, particularly during heatwaves and between 4pm and 8pm, "when most people arrive home and switch on their ACs, TVs, lights and other household appliances."[45] Significant demand for AC occurs at peak times: we estimate that out of total electricity demand for cooling globally, cooling at peak times makes up 61.3%. In the US, over 75% of electricity demand for space cooling is at peak times.[46]

Rising demand for cooling has been driving increases in peak electricity demand in both developed and developing countries. In July 2020, on a hot summer day in Texas, customers of El Paso Electric Company (EPE) met a new peak electricity demand of 2,173 MW. EPE had not expected this level of peak demand until 2026.[47] Peak demand is also rising in countries where AC uptake is expanding rapidly. In the Maghreb region in North Africa, peak demand increased by 6% annually from 2004 to 2013, which coincided with a rapid increase in the use of AC and rising temperatures in the region.[48] In California's heatwave in August 2020, cooling devices accounted for 50% of peak energy demand.[49]

As heatwaves become more frequent and incomes rise, particularly in hot countries, we expect cooling to drive further increases in peak electricity demand. The power sector will have to handle both overall increases in demand and extreme peak demand increases. One study estimates that in the US, by mid-century, peak per-capita summertime loads may rise by 4.2%–15% on average due to increases in ambient air temperature.[50,51] In India, the IEA expects space cooling to rise from 10% of peak electricity load in 2016 to 45% by 2050.[52] And these estimates are country averages: local grids can see much greater strains. For example, cooling accounted for 52% of Beijing's peak electricity demand during the 2017 heatwave.[53] Other drivers of peak electricity demand include the rollout and uptake of EV charging (see below).

In the summertime

Share of space cooling in peak electricity load by country/region (2016 and 2050, %)



Note: The shares have been calculated for the time within the year at which the peak load of overall electricity demand occurs.

Source: IEA [54]

Electric vehicles and peak demand

The EIU is launching a report in late 2020 titled, "Cooling: Transporting us to net zero", which identifies the impact of cooling on EV energy usage and the contribution that efficient, climate-friendly cooling can make in increasing EV uptake. It assesses how cooling is used in EVs and estimates how a shift to more efficient cooling would improve battery range, as well as reduce costs and emissions.

An increase in EV uptake means an increase in EV charging. If people charge their EVs using fast-charging during peak times, peak demand will rise accordingly. The IEA estimates that the share of EV charging in peak demand could rise to as high as 4-10% by 2030, up from 0.3% today.[55] Other studies have estimated the contribution of battery electric vehicles (BEV) charging to peak load at about 6% of the total peak load by 2030.[56]

The power sector is not ready for this rise in demand. One 2018 study in the UK states that "distribution and transmission networks were not designed for EV demand from homes with off-street parking and potentially we do not have sufficient network capacity for mass-uptake."[57]

Educating EV consumers to charge outside of peak demand times is critical. One solution is "smart by design" EVs that charge overnight but pause during peak periods.[58] Additionally, the car and truck industry must invest in more efficient cooling to prolong battery life and reduce electricity consumption. This is particularly the case where ambient temperatures are high – above 25°C – since, according to EIU analysis, cooling requirements can reduce battery range by 17%[59] and account for almost 45% of EV electricity requirements.

The need for affordable, net zero electricity

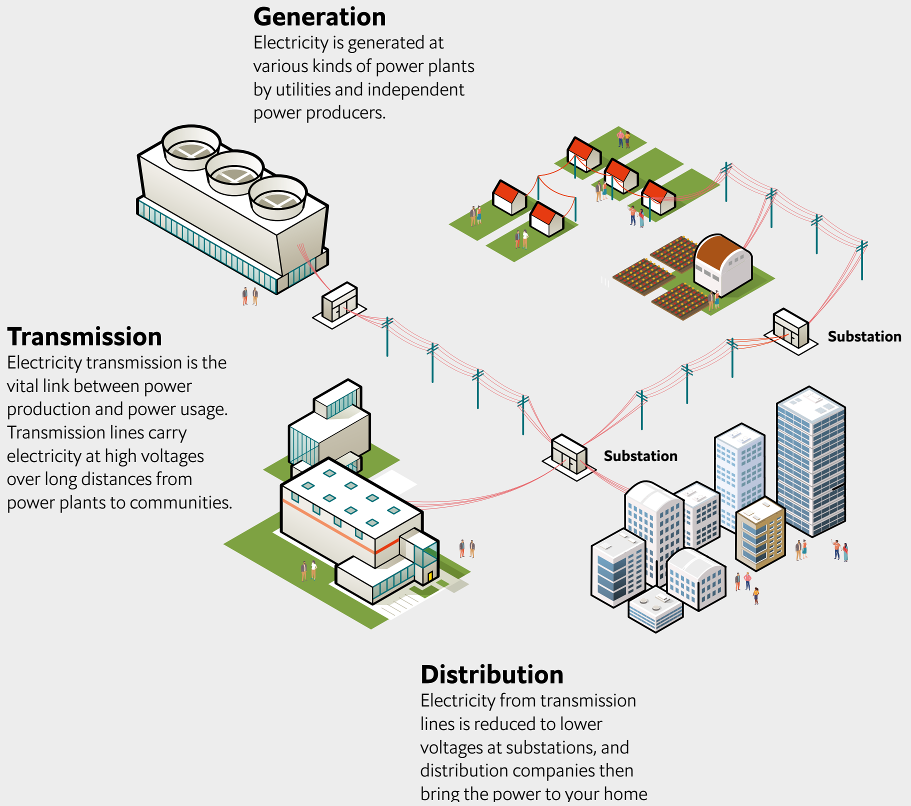
Given the benefits of space cooling, preventing people from buying and using AC units is not an option. Neither is allowing power outages, and the risks they create, a viable strategy. One option that energy companies might consider is building additional capacity in the form of new power plants, as well as transmission and distribution networks.

Alternatively, they could support providing the same amount of cooling more efficiently.

Financial costs

Building additional power capacity brings significant financial costs throughout the supply chain.

Who's got the power?
Key components of the power sector



Source: Indiana Business Research Center[60]

Paying the price

Typical costs throughout the power supply chain

Generation costs[61]

Fixed costs – the costs of building the plant (including environmental approvals), land acquisition, grid connection (in some instances).[62]

Operating costs – the costs of running a plant, fuel costs (generally free for renewables), labour and maintenance costs, insurance and local authority rates.[63]

Transmission and distribution costs

Fixed costs – the production of electric power lines and transformers, products to detect failures, substation and line management systems (e.g. smart-grid technology).

Operating costs – maintenance (although this is usually sold through contracts). At the margin, the cost of loading a given transmission line with additional electricity is effectively zero.[64]

The installation and maintenance of power plants of all fuel types incur costs. While renewables are inexpensive to run compared with fossil fuels, they have traditionally been very expensive to build and install.[65] In recent years, these building costs have fallen substantially – the price of electricity generation from solar photovoltaics (PV) fell 82% between 2010 and 2019[66,67] – but a solar farm that supplies 200 US households can cost $1m to install.[68]

Building additional power capacity has environmental costs too

Building new power plants to meet growing demand for cooling can have implications for the environment. Cooling devices need electricity to function, so if the power is generated from fossil fuels this will contribute to CO_2 emissions. Thus emissions from power generation are strongly related to the fuel mix.

$$$

Meeting peak demand is particularly costly

Power providers have to keep backup generation capacity online so that it can be ramped up at a moment's notice during times of peak demand. This is often for just a few hours or days a year. The owners of peaker plants[69] are compensated either with a capacity payment to make this peak capacity available at all times, or with a very high tariff for the power supplied at the time it is needed.[70] During the heatwave in California in August 2020, wholesale power prices quadrupled between 5pm and 7pm.[71]

As Kristen Taddonio, Senior Climate and Energy Advisor at IGSD, stated, "matching demand with resources is easy for the first 60-80% of electricity demand, it's the last 20% that is the most difficult and therefore costly." To ensure supply is available in transmission and distribution networks, power providers have to anticipate levels of peak demand and run large networks to make sure they can meet it. This is inefficient and costly.

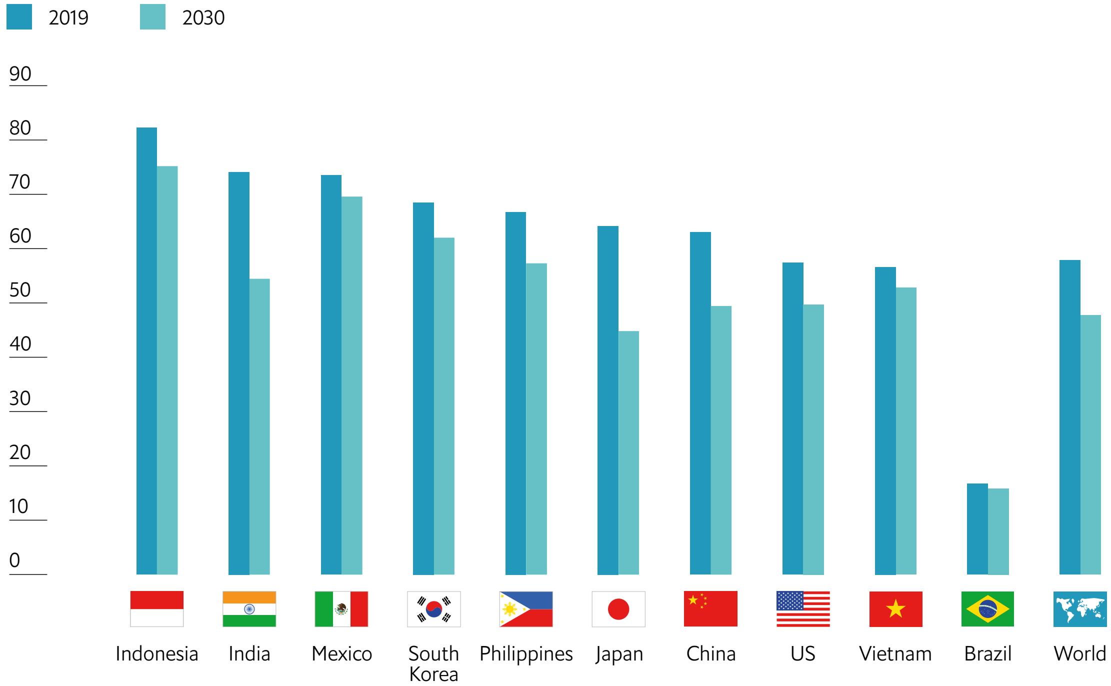
Peaker plants are not only expensive but also highly polluting. They are generally the most inefficient types of fossil fuel-based power plants and so contribute more to global emissions than power plants typically used to meet electricity during non-peak times.[72,73]

Generating power to meet growing demand for cooling will cost US$4.6trn between 2020 and 2030

The cost of renewables has implications for the power sector, not least because more and more countries are moving away from fossil fuels to greener alternatives. The EIU forecasts the share of fossil fuels in the global energy mix to decline from 56% to 47% by 2030, replaced by renewables.[74]Assuming this pace of shift to renewables, and if nothing is done to reduce or replace the demand for electricity from cooling, our analysis shows that the total financial costs of generating electricity for space cooling globally are expected to grow from US$210bn ($32 per person) in 2010 to $550bn ($69 per person) by 2030. Between 2020 and 2030, $4.6trn will be spent on generating electricity for cooling.[75] Of this, 54% of the costs relate to generating and operating power plants used to meet peak demand, equivalent to only 25% of electricity consumption time.[76]

High voltage

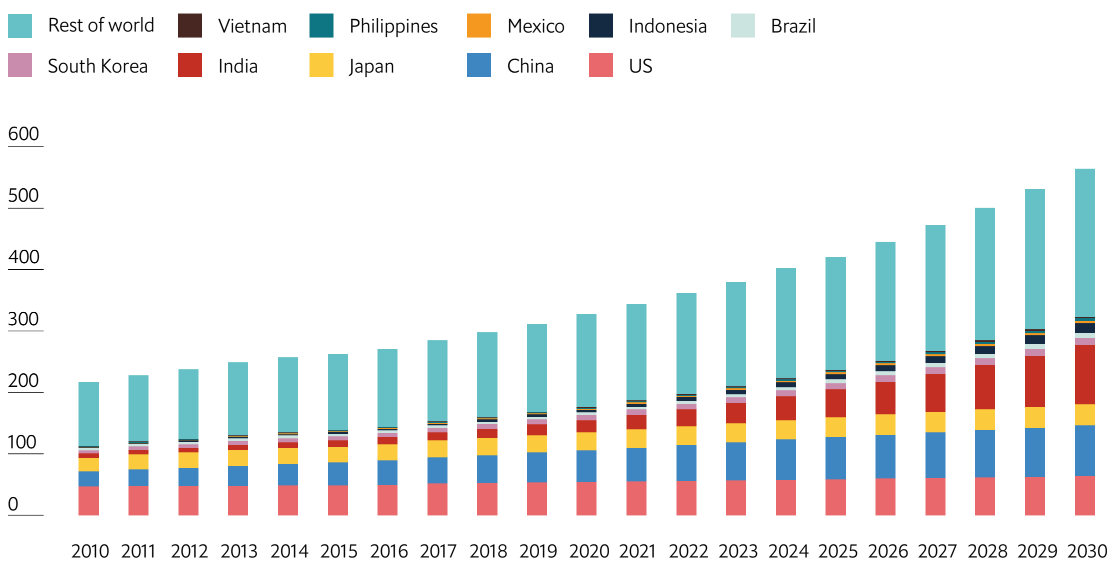
Share of fossil fuels in total fuel mix for power generation by country (2019 and 2030, % of total fuel generation)[77]



Source: EIU data and analysis

Surging costs

Total financial costs to generate electricity for space cooling by country/region, (2010-2030, US$bn)



Source: EIU analysis based on multiple sources

Transmission and distribution costs

Our estimates do not take into account the costs of expanding transmission and distribution networks to meet cooling demand. If they were accounted for, the costs outlined above would be even higher. One study on Indonesia estimates that for every $1 invested in additional power capacity, 40 cents are spent on the expansion of transmission and distribution networks.[78] By not including these costs and focusing only on the generation costs, our analysis may capture only 60% of the total costs incurred by increasing capacity.

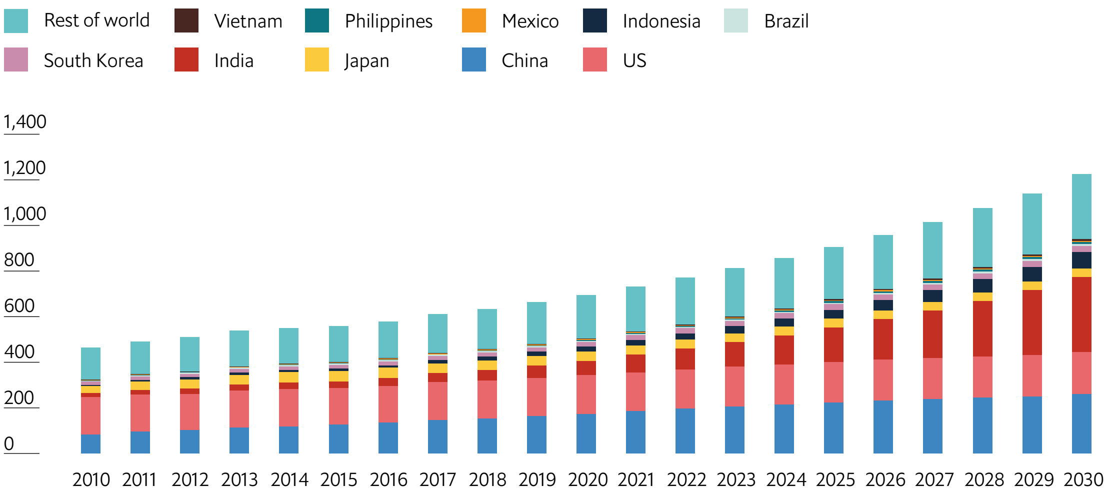
Space cooling will contribute 10.1 GtCO_2 emissions from electricity generation between 2020 and 2030[79,80]

Global indirect CO_2 emissions from electricity generation for space cooling have grown from 460 million tonnes (Mt) in 2010 to 690 Mt in 2020, and based on the EIU forecast for fuel mix out to 2030, emissions are expected to grow at an even faster rate to 1,210 Mt by 2030. Cumulatively, this means that from 2020 to 2030, 10,110 MtCO_2 emissions will be created from space cooling, of which 6,790 Mt (or 67%) will be generated as a result of peak electricity demand.[81]

Countries in hot regions and where incomes are rising are driving this growth in emissions. In India and Indonesia, for example, emissions from cooling are expected to grow at an annual rate of 17.8% and 13.0%, respectively, to 2030, compared with a global average growth of 5.7%. This increase in cooling emissions is driven, to a large extent, by growth in cooling demand and, to a smaller extent, by the relatively slow pace of transition away from fossil fuels in the energy mix.

Climbing emissions

Indirect CO_2 emissions for space cooling by country/region (2010-2030, MtCO_2)



Source: EIU analysis based on multiple sources

Direct and indirect emissions

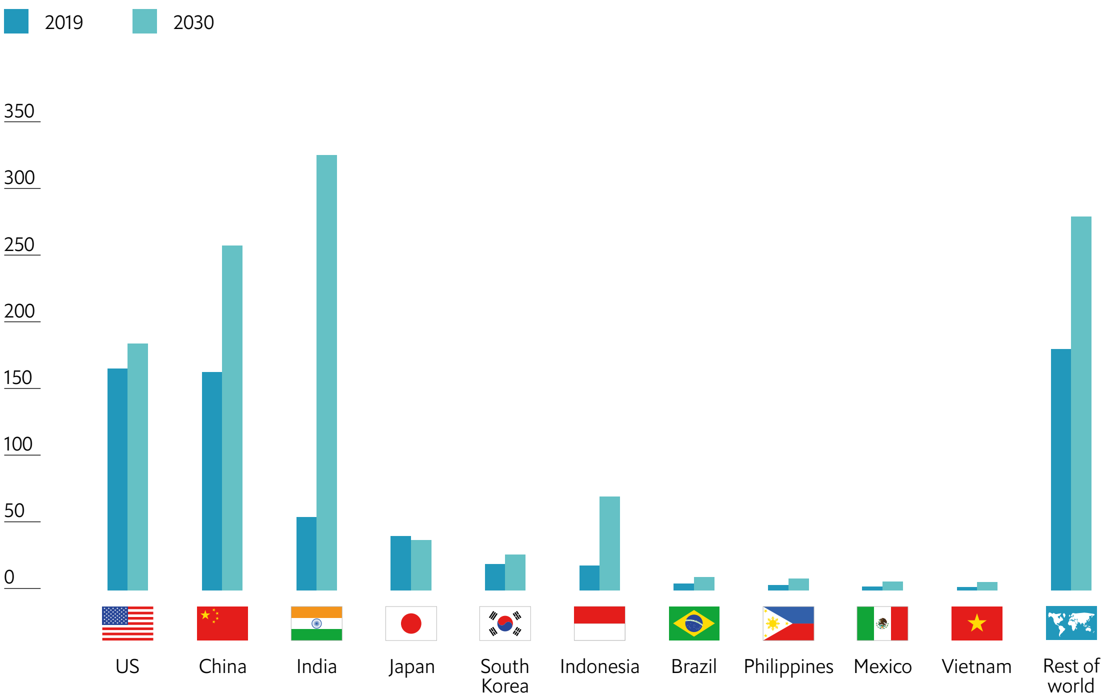
Our analysis looks only at indirect emissions, and excludes the direct emissions from the use and leakage of hydrochlorofluorocarbon (HCFC) or hydrofluorocarbon (HFC) refrigerants. As a result, it underestimates the emissions from space cooling.

Outpaced: Keeping up with cooling demand

The transition to renewable energy is not moving fast enough to keep pace with the growth in cooling demand. This came to light in 2017, a record year for solar growth, when 94 GW of total solar generation deployed globally were outweighed by the addition of 100 GW to the grid – just to meet demand for residential AC.[82] As renewable uptake is not fast enough, fossil fuels will continue to be used to meet electricity demand from cooling (particularly at peak times), and emissions from fossil fuel sources will rise out to 2030. Indirect emissions from space cooling in India are expected to increase from 55 $MtCO_2$ in 2019 to 326 $MtCO_2$ in 2030, despite an expected drop in the share of fossil fuels from 76% to 57% in the fuel mix.

Reaching new heights

Indirect CO_2 emissions for space cooling by country/region (2019 and 2030, $MtCO_2$)



Source: EIU analysis based on multiple sources

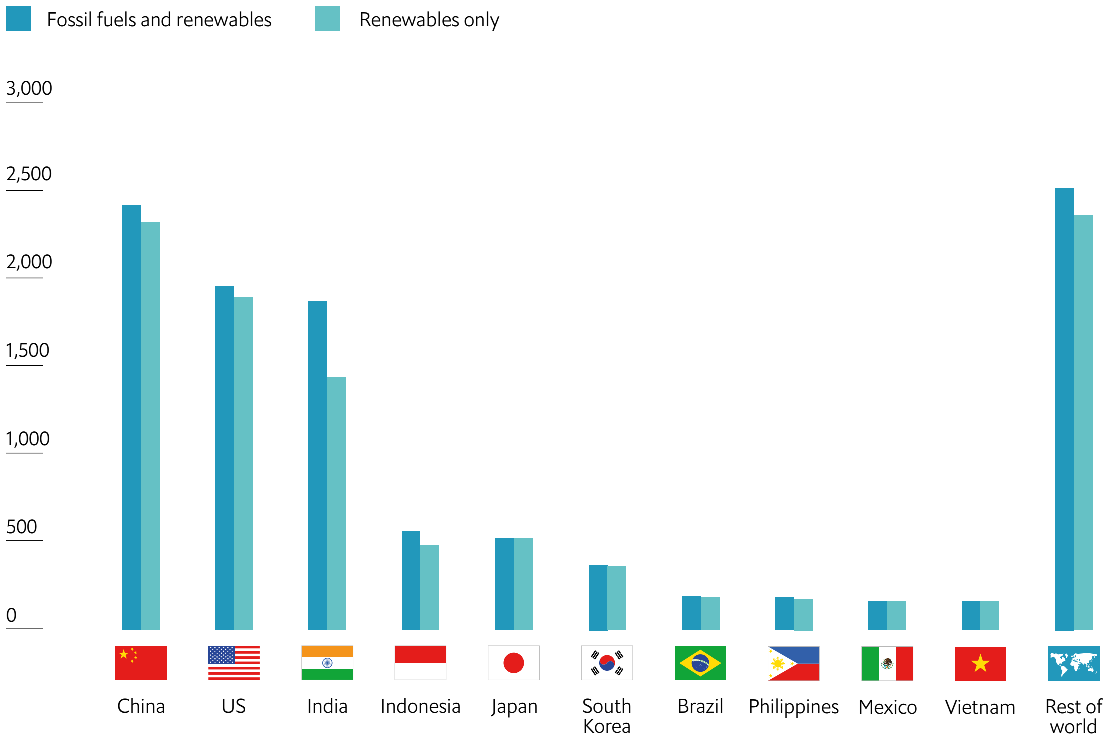
A more ambitious shift to renewables reduces some of the environmental costs of meeting demand for space cooling but does little to reduce the financial costs

Given the need to meet net zero emissions by 2050, it is hoped that policymakers will push for a more ambitious shift towards renewable energy than the EIU forecasts. Even if this happens, emissions will still be significant and financial costs will remain very high.

If all additional demand for electricity is met through renewables post-2025, overall emissions would be reduced. Globally, total indirect emissions from space cooling incurred between 2020 and 2030 could drop by over 9% from 10.1 $GtCO_2$ emissions to 9.2 $GtCO_2$ emissions. The impact across countries would differ. In India, where demand for cooling is expected to grow on average by 18% each year, CO_2 emissions could be reduced by as much 25% from the move, while in Japan, overall CO_2 emissions would be reduced by only 0.22%.

Shifting to sun and wind

Total emissions from generating electricity for space cooling by country/region under alternative scenarios of fuel generation (2020-2030, $MtCO_2$)



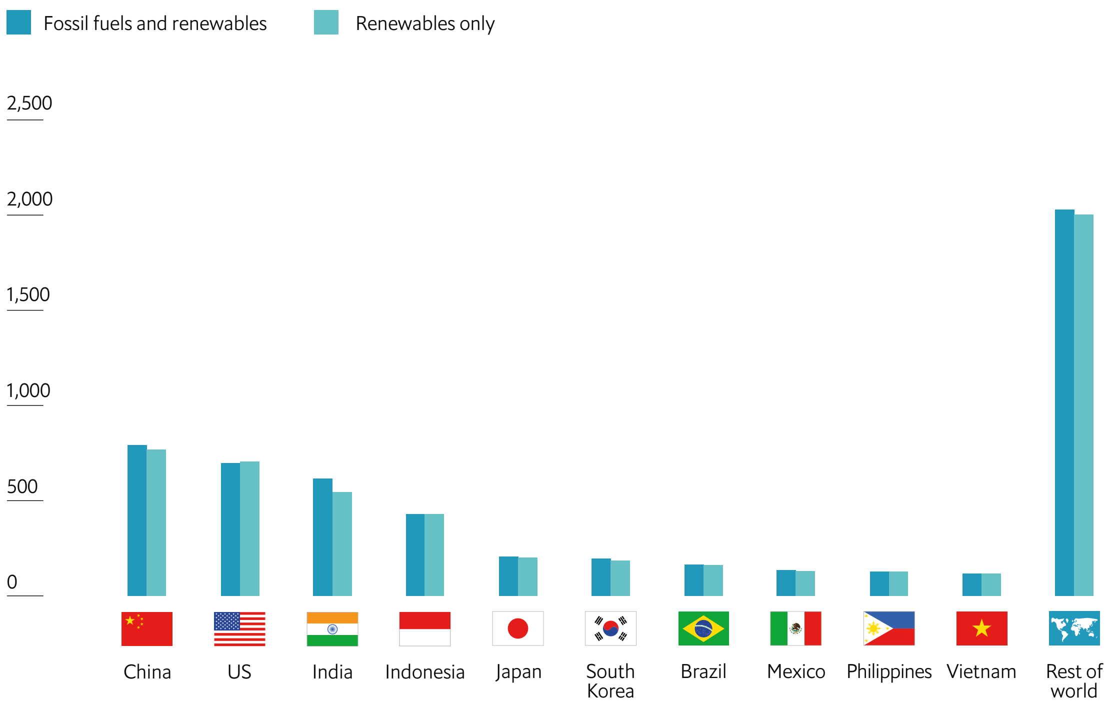
Source: EIU analysis based on multiple sources

However, while a shift towards renewables enables the same amount of electricity to be generated at a lower environmental cost, the financial cost remains high and would be only very slightly reduced, despite falling renewable costs. Our analysis shows that, at the global level, the financial costs incurred between 2020 and 2030 would drop by almost 3% from US$4.6trn to $4.5trn.

Even if we assume this more ambitious shift to renewable energy, electricity usage from space cooling will still result in a financial cost of US$4.5trn and 9.2 $GtCO_2$ emissions by 2030. Approaches to reduce electricity demand from space cooling need to be considered alongside the shift to renewables.

Limited cost reductions

Total financial costs of generating electricity for space cooling by country/region under alternative scenarios of fuel generation (2020-2030, US$bn)



Source: EIU analysis based on multiple sources

Methodology note

Baseline financial costs and emissions associated with growth in cooling demand under a "do-nothing" scenario have been estimated using a number of assumptions:

1. We estimate the financial costs incurred in generating electricity using assumptions on the levelised cost of electricity of different fuel types across different countries, estimated based on IEA data.

2. We estimate the emissions incurred in generating electricity using assumptions on the emission intensity of different fuel types across different countries based on data from the EIU (see appendix).

3. To account for differences in both financial costs and emissions associated with peak electricity demand for cooling, we assume that peak electricity demand is generated through fossil fuel combustion only.

4. We account for loss of electricity in transmission and distribution which adds financial costs and emissions from providing electricity for space cooling. Losses as a percentage of output are estimated using World Bank data and range from 3.4% in South Korea to 19.3% in India, with a global average of 8.3%.

See the Methodology section on page 45 for further detail on the methodology and assumptions used in the analysis.

More efficient cooling can save money and emissions

We have already established that building extra capacity to meet rising cooling demand incurs both financial costs and emissions. One option to avoid power outages and at the same time minimise costs and emissions is to meet cooling needs while using less electricity. There are two ways to reduce electricity consumption in space cooling: first by improving the efficiency of AC units directly, and second, by reducing the need for an AC unit in the first place. When other solutions, such as demand-side response programmes and thermal energy storage, are combined with efficient cooling, the financial and environmental costs of cooling can also be reduced. These solutions are explored in the next section.

Improve and reduce

Improving the efficiency of cooling and reducing the need for mechanical cooling are two pillars of the Cool Coalition's approach to closing the cooling gap and meeting future demand without dramatically increasing emissions. This report considers the implications of an ambitious shift to renewables, but does not explore ways to protect vulnerable people or leverage cooperation.[83] For guidance on these issues, see the Sustainable Energy for All (SEforAll) Chilling Prospects series and the Cool Coalition's homepage.

The Cool Coalition's approach to meeting cooling needs[84]

Covered in this report — Not covered in this report

REDUCE where possible the need for mechanical cooling through better urban planning and building design, and the use of nature-based solutions such as green public spaces and green roofs and walls.

SHIFT cooling to renewables, district cooling approaches.

IMPROVE conventional cooling by increasing the efficiency of AC and refrigeration equipment and demand response measures.

PROTECT vulnerable people from the effects of extreme heat and the consequences of unreliable medical and agricultural cold chains.

LEVERAGE cooperation between stakeholders active in cooling to achieve a greater collective impact.

Making AC units more efficient

AC appliances lower temperatures and humidity to make indoor spaces more comfortable. To improve the efficiency of AC units, manufacturers could use updated and improved internal components such as compressors, condensers, expansion valves and heat exchangers.[85] Consumers can also play a part in improving efficiency by following best practices in maintaining equipment. Poor maintenance, such as not clearing obstructed air vents, can increase energy needs by 25%.[86]

Setting minimum performance standards

One approach to improving the efficiency of AC is to phase out the most inefficient appliances. Policymakers could introduce minimum energy performance (MEP) standards that an appliance must meet before it can be sold commercially.[87]Such standards could be made either mandatory or voluntary.[88] CLASP is a non-profit organisation that works to improve appliance efficiency policies globally. According to its Policy Database, almost 70 countries have introduced standards for room AC units since 1988.[89]

As recently as July 2020, China increased its MEP standards for room AC units by 15%, and proposed further increases in 2022 that will place it among the world leaders for AC efficiency.[90]The standards will apply only to the domestic market, but the efficiency gains will be significant as China's consumers account for 45% of the world's installed room AC units. Since Chinese businesses produce 70% of the world's supply of such appliances, it is hoped that improvements in the domestic market will spill over into the products manufactured for export.[91] Mirka della Cava, Head of Policies, Standards, and Programs at the Kigali Cooling Efficiency Program, states that "You can hope that export production will be brought up to par by the improvements in domestic manufacturing. Driving change through the manufacturers will of course be much more effective, but it is important not to lose sight of the continued need to raise the level of the minimum energy performance standards in importing countries."

Minimum energy standards look different in every country – they depend on local circumstances, such as temperature and the availability and price of products. The UNEP U4E Model Regulation Guidelines provide voluntary guidance for governments that are considering regulatory changes requiring more energy-efficient AC units. The guidance offers different levels of ambition for countries to aspire to.[92]

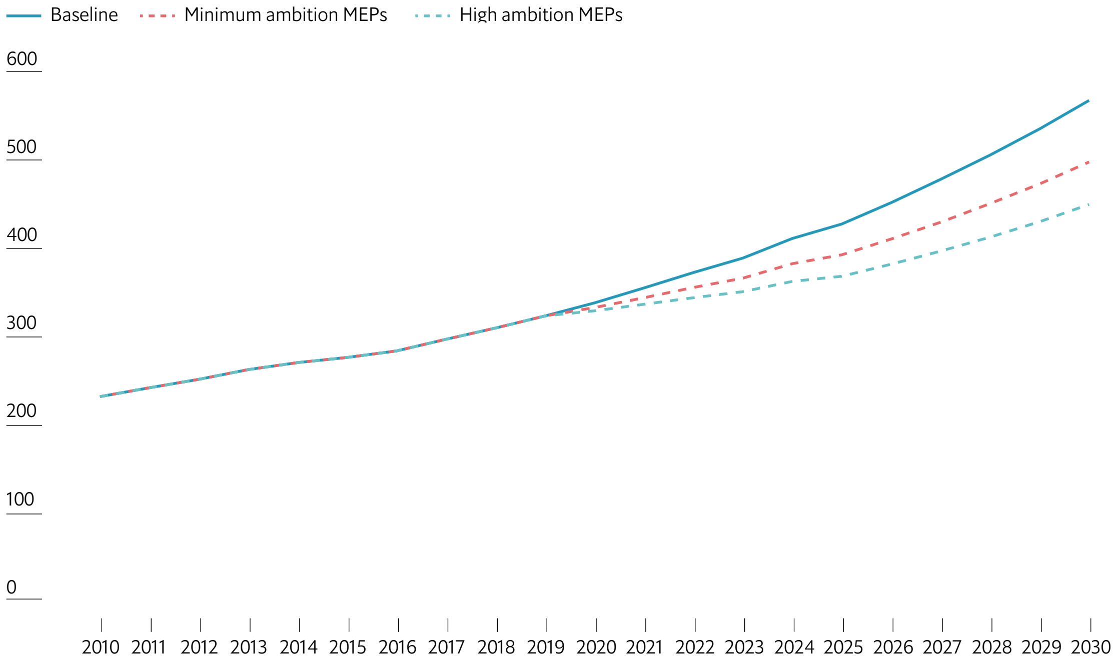
Globally, we estimate that rolling out minimum ambition standards across all new residential and commercial AC units[93] could reduce total electricity demand by 11.8% by 2030. This is equivalent to 700 TWh of electricity generation. Setting a higher ambition for standards could result in a reduction of approximately 20% in 2030, or 1,200 TWh of required electricity generation.

The magnitude of potential gains for a country depends on the size of its cooling market and the current levels of efficiency of products sold. Countries with a larger market and/or greater levels of inefficiency in their existing products could gain more from a transition. The Philippines, for example, could reduce total electricity demand by 35-50% in 2030 by implementing minimum standards, depending on its level of ambition. In Japan, where AC units are already more efficient, the potential reduction in electricity demand ranges between 14% and 24%.

Our analysis shows that the reduction in electricity demand from introducing standards for new AC units will also reduce the financial cost of generation by 13-22% – equivalent to savings of up to US$120bn by 2030. Similarly, emissions could be reduced by 12-20% by 2030, or up to 250 MtCO_2.[94]

Setting standards

Global financial costs of generating electricity for space cooling under alternative scenarios from implementing MEP standards (US$bn)



Source: EIU analysis based on multiple sources

Challenges with rolling out standards

Establishing AC standards can drive inefficient products out of the market, but rolling out such standards can be challenging. In countries that manufacture AC units, standards mean that some of the units produced will no longer be legally accepted in the market.[95] Local manufacturers can be directly impacted through the loss of domestic sales.

Another growing concern is that, due to the variability of standards across countries, adopting standards can encourage the export of low-efficiency products. In order to protect local businesses against sales losses, products that do not meet new standards can be exported, often at a lower price ("dumping"). Standards are often less stringent in low-income, high-temperature regions where demand for AC is rapidly growing,[96] meaning that less-efficient, environmentally harmful products sold at lower prices will be readily accepted. A report by CLASP, for example, finds that 35% of room AC units sold in countries across Africa are low-efficiency.[97] While standards can reduce emissions in countries where they are adopted, dumping can export emissions to other countries, reducing net global benefits.

A combination of anti-dumping policies, widescale regional coordination in the adoption of MEP standards, and support schemes for local manufacturers can help mitigate these impacts.

A more ambitious option is to roll out the best available technology globally

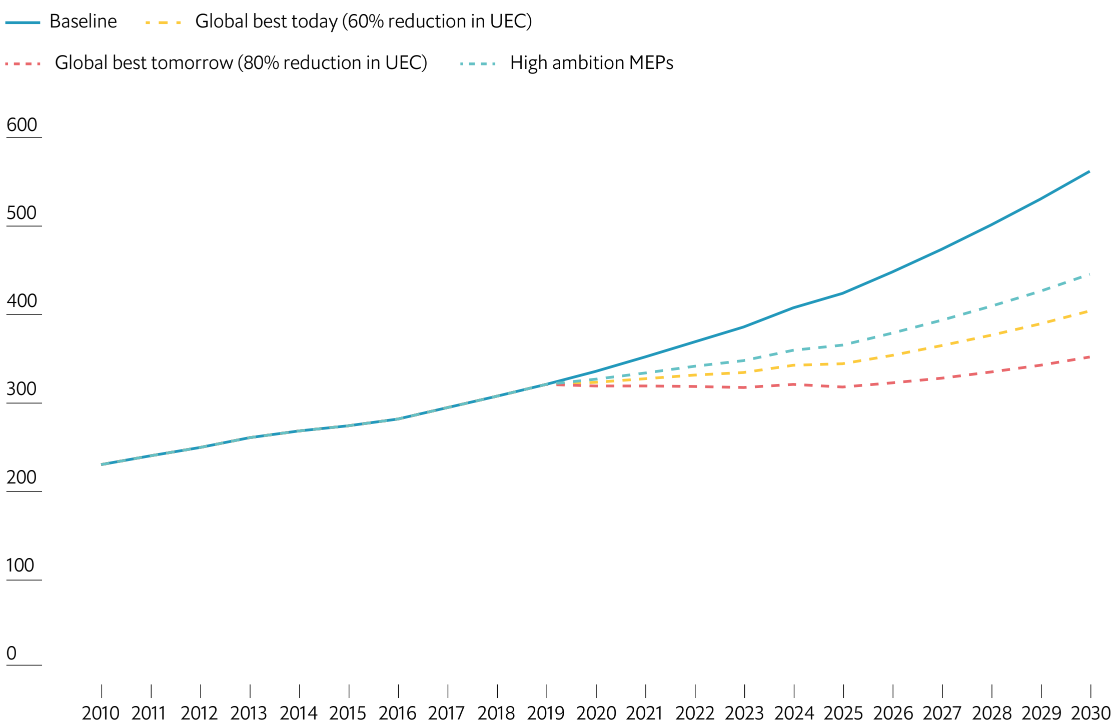
Another approach to AC efficiency focuses on rolling out the best available technology globally, rather than removing the most inefficient products from the market. A 2019 paper published by the Lawrence Berkeley National Laboratory (LBNL) suggests that making this change could reduce the electricity consumption of an AC unit by 49-70%, depending on equipment type.[98,99]

New innovations could push this even further. The Rocky Mountain Institute's Global Cooling Prize is bringing together manufacturers, academics and laboratories in a competition to develop a residential cooling technology that has at least five times less climate impact than a typical AC unit available today (or an almost 80% reduction in energy consumption).[100] Using the various estimates of potential savings, the EIU has modelled the impacts associated with a reduction in the electricity consumption of an AC unit from the "best available today" and one that could be on the market tomorrow, the "best available tomorrow".[101]

Our analysis finds that a global transition towards the best cooling technologies for all new AC units could achieve a total reduction in electricity demand of 29-38% by 2030. This is equivalent to savings of 1,700-2,260 TWh of electricity generation, cost reductions of US$210bn, and emissions reductions of up to 470 MtCO_2.[102] The highest level of savings in 2030 in absolute terms could be achieved in India (up to 530 TWh of electricity generation), followed by China (up to 500 TWh) and the US (up to 160 TWh).

Aiming for the global best

Global financial costs of generating electricity for space cooling under alternative scenarios from direct improvements to AC units (US$bn)



Source: EIU analysis based on multiple sources

Even greater cost savings can be achieved through reducing the need for an AC unit in the first place

While improving the efficiency of AC units goes some way to reduce electricity use, a more effective strategy would be to reduce the need for ACs. Solutions to improve the efficiency of AC units impact only future AC sales, so efficiency gains take time to feed through. Reducing the need for AC can have an immediate impact on total electricity consumption, and there are a whole host of creative ways of doing this.

Keeping cool without AC

Changing consumer behaviour to adapt to being comfortable in slightly higher temperatures is one option. The India National Cooling Action Plan 2019 estimates that, by increasing the minimum thermostat setting from 20°C to 24°C, it is possible to save 20% of annual energy consumption.[103] People can also adapt their clothing. For example, the Ministry of the Environment in Japan launched the "Cool Biz" campaign in 2005, encouraging offices to set the AC temperature to no less than 28°C and allowing employees to wear casual clothing in the summer instead of formal business wear. In its first year, the campaign resulted in an estimated 460,000-ton reduction in CO_2 emissions.[104]

Building design influences whether occupants need AC. This spans everything from building orientation – windows facing east or west tend to capture the most sun, as they are exposed to it when the sun is low in the sky in the morning or afternoon[105] – to construction materials. According to the IEA, insulating walls, roofs and windows can reduce energy needs for cooling by 10-40% in hot climates.[106, 107] One study estimates that controlling for window design, size and orientation can reduce cooling loads by 30%.[108]

And it is not only design that can have impact: buildings can also use sensors and smart systems to determine room temperature based on, for example, the number of occupants at any given time.[109] And people themselves can adjust to temperatures. As we use more mechanical cooling, our bodies become accustomed to lower temperatures. Jessica Grove Smith from the Passive House Institute explains that if buildings can be designed in a way that allows people to feel comfortable from the outset, then it is possible to reduce the need for mechanical cooling by 50-80%. Iain Campbell, Senior Fellow at the Rocky Mountain Institute, highlights the importance of designing buildings with climate in mind, since "it is much cheaper to design buildings well in the first place than to take an existing building and change the envelope".

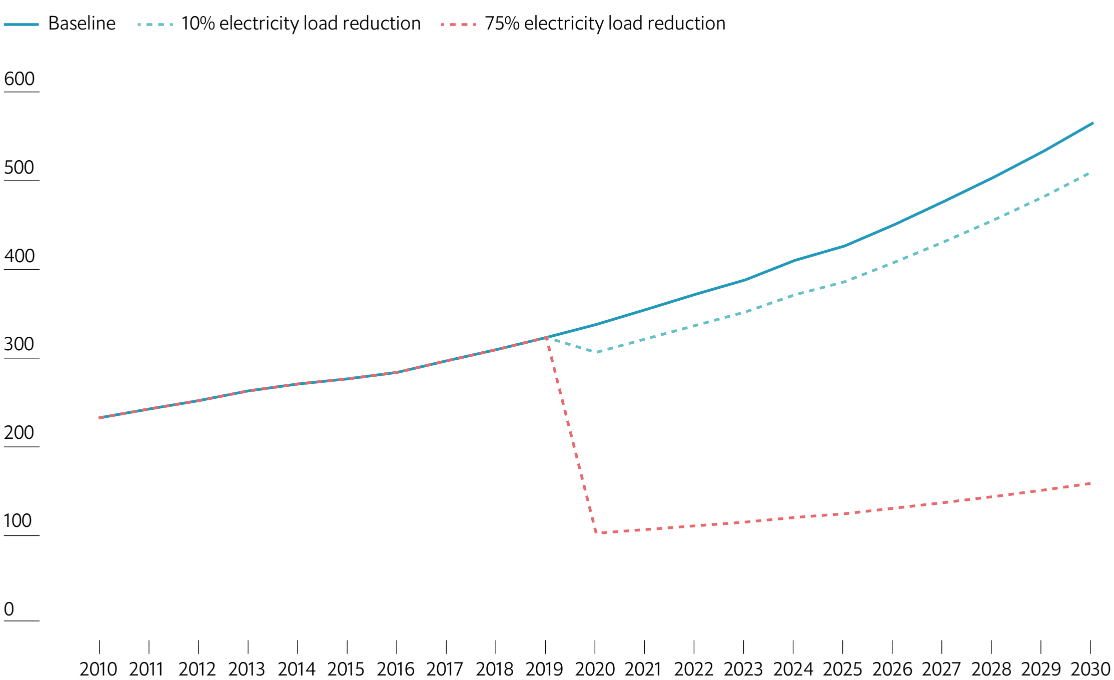
Roof materials can absorb huge amounts of solar energy. One study estimates that dark roofs reach over 66°C on the average hot day,[110] whereas roofs treated with reflective paint, or comprising reflective tiles or sheet coverings, are protected against heat absorption.[111] The use of reflective roof coatings can reduce the need for space cooling by up to 70%.[112] Using reflective paint and vegetation to cool pavements can also help reduce the heat effect, especially in urban areas.[113]

Green spaces and urban planning, including shaded street infrastructure in cities, can reduce the urban heat island effect –whereby the heat generated by buildings, transport and high population density can make metropolitan areas 1-3°C warmer than surrounding areas.[114] Investing US$100m a year in urban tree planting globally could reduce average temperatures by 1°C on hot days, potentially providing relief for 77m people.[115] In the city of Medellín, Colombia's green corridors have reduced temperatures by up to 3°C.[116]If greening the streets is not viable or is exhausted, green roofs can reduce building energy use by 0.7%.[117]

The rollout of these measures could translate into a reduction in electricity demand for cooling of 10-75%, feeding through into a reduction in the financial costs of power generation of US$55bn to $410bn by 2030, and reducing emissions by between 120 $MtCO_2$ and 910 $MtCO_2$.[118] Combining these measures with a more ambitious shift to renewables could generate even greater cost savings.[119]

Cutting costs

Global financial costs of generating electricity for space cooling under alternative scenarios from implementing measures to reduce electricity consumption (US$bn)



Source: EIU analysis based on multiple sources

Getting more bang for your buck

Overall costs and savings (EIU fuel mix)

Measure	Financial cost savings to 2030[120]	Emissions savings to 2030
Standards (high-ambition MEP standards)	**15%** (equivalent to US$670bn)	**14%** (equivalent to 1,400 $MtCO_2$)
Best available technology today	**20%** (equivalent to US$910bn)	**20%** (equivalent to 1,990 $MtCO_2$)
Best available technology tomorrow (Rocky Mountain Cooling Prize solutions with 80% efficiency improvements)	**26%** (equivalent to US$1,210bn)	**26%** (equivalent to 2,660 $MtCO_2$)
Reduce the need for mechanical cooling (by up to 75%)	**75%** (equivalent to US$3,450bn)	**75%** (equivalent to 7,580 $MtCO_2$)

Source: EIU analysis based on multiple sources

The speed of transition to net zero

Countries aim to meet net zero carbon emissions by 2050 in developed economies and by 2060 across the developing world.[121] Analysis by the Energy Transitions Commission (ETC) finds that, under a zero-carbon pathway, energy demand globally would need to be reduced by as much as 15% by 2050.[122] This will require a combination of decarbonisation and reducing the energy consumption of products – and avoiding the need for them altogether where possible. Our analysis shows that without the implementation of direct or indirect cooling solutions, the transition to net zero emissions could extend beyond 2050, risking higher levels of global warming. Efficient cooling can make the transition to net zero happen both more rapidly, and at a lower cost.

Implications on the speed to net zero

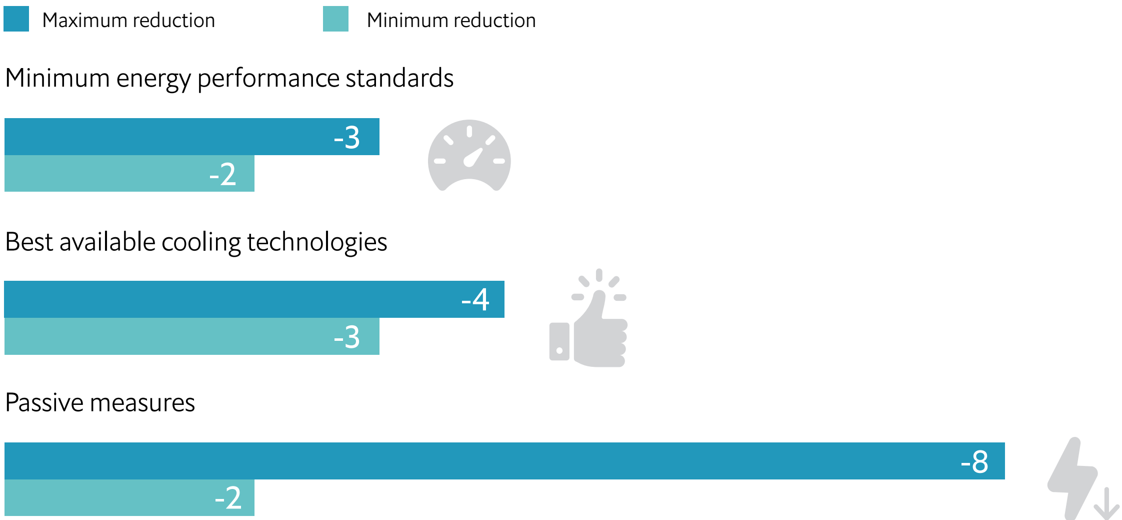
Implementing minimum energy performance standards reduce the number of years required to achieve net zero emissions by up to 2-3 years under the minimum and high ambition scenarios respectively. Without these measures, net zero emission targets may only be achieved by 2053 instead of 2050.

Implementing best available cooling technologies globally could increase the speed of transition to net zero emissions by 3-4 years under different scenarios of a reduction in the energy consumption of AC units ranging between 60-80%. Without these measures, net zero emission targets may only be achieved by 2054 instead of 2050.

Reducing electricity demand for cooling by 10-75% through wider measures such as improving building design and urban planning could allow for a quicker transition to net zero emissions by 2-8 years. Without these measures, net zero emission targets may not be achieved until 2058 instead of 2050.

A stitch in time saves nine

Reduction in number of years required to achieve net zero emissions by 2050 by implementing energy-efficient cooling solutions



Source: EIU analysis based on multiple sources

The economic benefits of a clean recovery: The case for energy-efficient cooling

In attempting to regain economic growth in the wake of COVID-19, policymakers are looking to launch policies and programmes that deliver jobs and stimulate additional spending and that can be implemented quickly and easily. In August 2020, the EIU published a report looking at the economic benefits of energy efficiency policies. It highlighted that spending on energy efficiency creates 77 jobs per US$10m invested, compared with just 27 jobs for the same amount of spending on fossil fuels. The effect may be even greater for improving building efficiency, with 90-300 jobs created for every $10m spent.[123,124] Policymakers should consider the economic benefits of including energy efficiency, including for cooling, in longer-term recovery packages. Read the report here.

Other solutions can also help when combined with efficient cooling

This section explores complementary solutions to mitigating the costs of rising electricity demand, and compares their benefits with their financial costs and emissions. It also considers how these solutions can interact with energy-efficient cooling to reach net zero.

Other solutions

Solution	How it solves challenge of rising electricity demand	Challenges with rollout
Demand-side response	Shifts electricity use to non-peak times.	Requires data; shifts electricity use to reduce peak costs but does not reduce it altogether; can raise prices for consumers.
Battery energy storage	Stores renewable energy to be used at a later time.	Expensive; shifts electricity use to reduce peak costs but does not reduce it altogether; environmental concerns if not disposed of correctly.
Hydrogen energy storage	Stores renewable energy to be used at a later time.	Inefficient distribution of energy is required; shifts electricity use to reduce peak costs but does not reduce it altogether.
Thermal energy storage	Stores renewable energy to be used at a later time.	Shifts electricity use to reduce peak costs but does not reduce it altogether.

Demand-side response programmes

Power providers can use demand-side response programmes to reduce peak electricity demand and its associated costs.[125,126] These programmes involve power providers using price signals and financial incentives to call on electricity users to shift or reduce their demand at a particular time, either by turning down or turning off non-essential services.[127] These programmes target consumers who can be flexible about when they can use electricity. Iain Campbell of the Rocky Mountain Institute notes that "power providers – both utilities and grid operators – tend to look at large loads that can be shifted that can have the greatest impact." Industrial and large commercial users currently dominate most demand response programmes.[128] Demand-side response aggregators bring together smaller electricity users so that, collectively, they shift or reduce electricity consumption.

Depending on the structure of the electricity market and the type of electricity customer the power provider is targeting, pricing, direct control and capacity markets can all incentivise consumers to shift or reduce their demand for electricity at peak times. For example, using "critical peak rebates", the power provider anticipates the peak demand period, informs consumers before it occurs, and offers them a rebate – a partial refund – for reducing demand during that time.[129]Direct control is another approach generally used for residential markets. Under direct control programmes, the provider makes a yearly payment to the participant in return for being able to exercise control over enrolled equipment during times of peak load.[130]

Capacity markets rely on consumers participating in a programme where they commit to "making a set amount of capacity available during a stress event".[131] They enable users to make money by committing to reduce demand during such an emergency, even if they are not required to act on that commitment. EDF claims that end-users can expect a request to shift or reduce electricity consumption only once or twice per year.[132]

Demand-side response programmes are quick to roll out and are becoming easier to operate with advances in smart meter infrastructure[133,134]– and they can save participants money. According to ComEd, an electricity supplier, "typical participants have saved an average of more than 15% compared to what they would have paid for electricity on the standard ComEd fixed-price rate."[135] These programmes can reduce the costs associated with generating and distributing electricity at peak times. One study estimates that implementing demand response for AC between 2pm and 4pm in commercial offices in Japan can reduce peak electricity demand from the energy provider, TEPCO, by 5%. The study indicates that the savings potential is large given Japan's reserve margin – the excess capacity retained to meet peak demand[136] – is 8-10%.[137]

However, developing reliable, time-varying, and geographically specific estimates of the potential of various end-uses of electricity requires significant input data.[138] According to Iain Campbell, "in the early stages, there is a significant level of complexity in running demand-side programmes – you have to verify that savings are achieved." In the residential sector, the hardware and communications requirements can be intrusive for homeowners.[139] In some instances, consumers have attempted to game the system, and ComEd has reported customers tampering with its AC curtailment systems.[140] As Iain Campbell explains, "some people wrapped silver foil around the utility sensor to prevent it from receiving the curtailment signal and kept their ACs on while pocketing the pay-out."

Case study: San Diego Gas & Electric Summer Saver programme, US

In 2005, San Diego Gas & Electric (SDG&E) launched the San Diego Gas & Electric Summer Saver programme.[141,142] Offered from April through to October, it enables residential and small commercial customers to allow SDG&E to control AC units in certain high-demand periods.[143] In return, customers receive a credit at the end of the year, based on their participation level and AC unit tonnage. Customers and businesses can choose between 50% and 100% reductions in AC use, with different levels of compensation.[144]

The programme has shown some signs of success: SDG&E claimed to have achieved a 70 MW power reduction during a 2014 heatwave and reported that conservation efforts by customers allowed it to provide reliable electricity throughout the event.[145,146] However, the programme has been criticised for being expensive and, at times, limited in its impact.[147] In 2015, regulators at the California Public Utilities Commission claimed that SDG&E had not undertaken sufficient outreach to educate its customers on Summer Saver options.[148] SDG&E itself cut 6,600 participants from the programme in 2017, stating that "little or no reduction" in load was made from those customers.[149] One potential solution could be to improve data collection to more accurately identify consumers who demand enough cooling to make reductions feasible and effective.[150]

Demand response programmes reduce the need for electricity generation and distribution at peak times when energy is most costly, both financially and environmentally. While such programmes reduce costs for utilities, they do not reduce emissions nearly as effectively as eradicating the need for AC can. If electricity users simply shift the time of day that they use the electricity rather than reducing consumption, power generation and distribution are still needed. And if these are sourced from fossil fuels, they contribute to emissions even if they avoid the need for peaking plants. Combining demand-side response programmes with measures to reduce the need for AC in the first place can bring the benefits of both.

Integrating energy efficiency into capacity markets: ISO-New England Capacity market, US

Directly integrating energy efficiency into power systems can drive savings in peak demand costs and energy use.

ISO-New England (ISO-NE) is an independent, not-for-profit corporation responsible for ensuring reliable and competitively priced electricity across the New England region. It operates a capacity market[151] to ensure that the power system has sufficient capacity to meet demand for electricity, particularly at peak times. It holds annual Forward Capacity Auctions where power suppliers compete to obtain a commitment to supply capacity in exchange for a capacity payment three years in advance of the delivery year.[152]

Since 2010, ISO-NE has invited customer-based demand-side resources, including demand-side response programmes and energy efficiency, to compete with conventional power generation resources.[153]

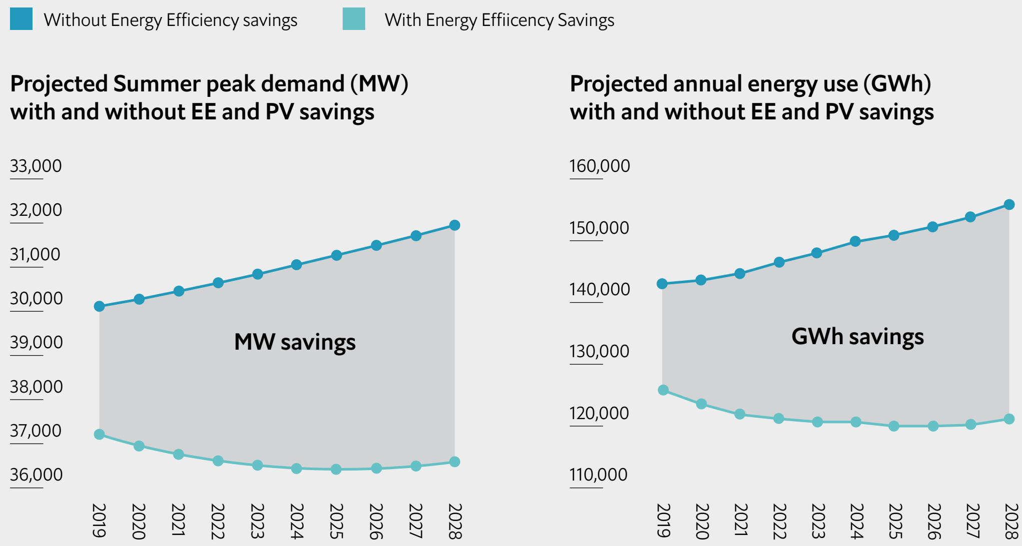
In practice, the programme requires power suppliers to commit to reducing energy demand at peak times through energy efficiency measures, thereby competing with power suppliers that only commit the extra capacity to meet electricity demand at peak times. Providers are penalised if they do not deliver on their commitments.[154] Energy efficiency received more than 6% of all capacity payments awarded in the 2017 auction. Most of the energy efficiency commitments in the ISO-NE capacity market come from utilities whose regulator obliges them to make such commitments.[155]

The requirements for demonstrating successfully delivered reductions in energy use are substantial. For example, Efficiency Vermont, which administers energy efficiency programmes in Vermont, reports that "up to 30% of the revenue received in the ISO-NE capacity auctions is taken up in the administrative costs of participating in the auctions and demonstrating compliance."[156]

However, the savings on peak demand and energy use are also significant. The figure below shows the savings resulting from energy efficiency measures to reduce peak demand and annual energy use. It reveals savings of nearly 20% for both summer peak demand and annual energy use.

Shaving the peak

Projected summer peak demand and annual energy use, with and without energy efficiency (EE) savings



Note: "Without Energy Efficiency savings" includes savings from solar PV resources, without these the peak demand / gross energy use would be even higher

Source: ISO-New England[157]

The transition to renewables – if there's sun and wind

There is a commonly held view that a shift to carbon-free electricity will solve the challenge of meeting growing electricity demand. But while an ambitious shift to renewable energy helps to reduce emissions from space cooling, it does little to reduce the financial costs of generating electricity for space cooling.

Beyond the financial costs of building additional renewable power capacity, renewables alone cannot solve the practical problems of meeting energy demand. Renewable energy sources are intermittent: they provide power only when the sun is shining or there is sufficient (but not too much) wind. And there is often a mismatch between when renewables can provide electricity and when people demand it. Solar power production drops off as electricity demand peaks in the evening, and overproduction (when more energy is produced than is needed) can occur in the middle of the day, putting pressure on the grid and potentially damaging it.[158] For example, in India, peak demand for cooling typically occurs at 7pm "when the sun has gone down and solar PV is no longer providing its full capacity".[159]

To date, curtailment – whereby electricity providers reduce the output of the plant or disconnect it altogether – has been the solution. Each unit curtailed is a unit not sold on the grid. The greater the curtailment, the more solar installations are not worth the cost.[160]A more ambitious shift to renewables will have to be combined with other solutions.

While shifting demand to different times of day through demand-side response programmes can help to offset the mismatch between renewable production and electricity demand, solutions to store electricity or thermal energy are also needed. There are multiple ways to store electricity – from pumped hydropower storage, which pumps water uphill to store it before releasing it downhill to provide energy when it is needed,[161] to liquid air energy storage, which converts air into nitrogen that can be used for electricity. Declining costs of renewable technologies in recent years have driven advances in energy storage, with momentum focused heavily on batteries and hydrogen.[162,163]

Offsetting the mismatch: Storing electricity using batteries

Battery energy storage systems present a solution to the renewables production and use mismatch. They can collect energy from a grid or power plant, store it and then discharge it when electricity is needed, allowing power system operators and utilities to store renewable energy for later use.[164] During periods of overproduction, energy can be stored until it is needed at peak times.

While this practical solution is effective, it is expensive. Lithium-ion batteries are the most common battery choice, and the production process is both time-consuming and expensive.[165,166]

The manufacturing and disposal of lithium-ion batteries also hurts the environment. According to a study by the European Commission, "Around 328 Wh [watt-hour] of energy is needed to produce just 1 Wh of lithium-ion battery capacity."[167] Moreover, lithium-ion batteries can leak toxic substances and are dangerous in landfill.[168] According to California regulations, all lithium batteries tested are classified as hazardous due to excessive levels of cobalt, copper, and nickel.[169] And, if that is not enough of a deterrent, recycling lithium-ion batteries is both challenging and energy intensive.[170]

Offsetting the mismatch: Storing electricity using hydrogen

Hydrogen offers another option for storing renewable energy. Excess renewable energy can be converted to hydrogen.[171] A fuel cell can then be used to convert the hydrogen to electricity or it can be directly injected into existing natural gas pipelines to heat homes.[172,173] The only waste products from hydrogen are heat and water.[174]

There is currently limited capacity for hydrogen and, although it could be expanded, the inefficiencies of the process outweigh the benefits (using fuel cells to release the electricity or sending hydrogen through the gas network doubles the energy conversion needed). Moreover, the process of electrolysis that is used to extract hydrogen requires electricity.[175]

Offsetting the mismatch: Storing thermal energy

An alternative solution is to store thermal energy – in other words, heat or cold.[176] Instead of converting energy into electricity and then converting it into cooling, this technology focuses on storing and moving energy as cold.[177] Enwave, a district energy operator in Chicago, uses storage technology to reduce AC electricity needs at peak times. It makes ice at night to deliver cooling to nearby buildings the following day.[178]

Waste heat or cold can also be "re-used". The regasification of liquified natural gas (LNG) – the conversion of gas to liquid to facilitate transportation – requires extremely low temperatures. This "cold energy" can be harnessed by nearby industrial users. According to one estimate, if half of the cold energy discarded during the process of regasification of LNG in the UK was recycled, it would equate to more than a fifth of the country's current cooling demand.[179]

According to Professor Toby Peters, "we need to start thinking thermally and at the system-level to create solutions that are fit for the need of the service, aggregate demand and harness waste and thermal energy streams rather than doing everything with electricity." Thermal energy storage can be done at a much lower cost than battery storage. Peters notes that thermal storage can cost around £15 per kilowatt-hour of energy compared with £250 for batteries.

Thermal energy storage can solve challenges surrounding peak time electricity costs, and re-using waste heat or cold can eliminate the need for electricity generation; but, if waste heat or cold are not used, electricity is still needed to make the cold during non-peak times. This incurs production and distribution costs, and, if these processes use fossil fuels, emissions.

Consumers, the power sector and policymakers all have reasons to care about cooling efficiency

Across all power systems there are generators, transmitters and distributors that produce electricity and deliver it to the consumer. The commercial structure of the power sector and the level of private-sector participation in a country determines the role of each key stakeholder, including *utilities, regulators and electricity retailers*.[180,181] These roles are critical to understanding the ways in which different stakeholders in electricity provision can benefit from efficient cooling.

Utilities both generate and sell electricity. In some countries, they are fully or predominantly government-owned, and the government determines prices and investment. In Indonesia, the state-owned Perusahaan Listrik Negara (PLN) controls the electricity market. It is responsible for most of Indonesia's electricity generation, and has almost exclusive control over the transmission, distribution and supply of electricity.[182]

In *regulated* markets, energy *regulators* oversee utilities. Utilities might be government- or privately owned, but the energy regulator sits as an independent body and is responsible for approving the utility's investment and pricing decisions. In India, there are regulatory bodies both at the national and local level. The Central Electricity Regulatory Commission (CERC) regulates the pricing decisions of companies that sell electricity in more than one state,[183] and the State Electricity Regulatory Commissions (SERCs) oversee the generation, distribution and transmission of electricity within a state.[184]

In *deregulated* markets, generation owners sell electricity to retail suppliers in wholesale markets. Customers choose their retail supplier, creating competition and allowing the market to decide where power is sourced and when investment in new power plants is required. Suppliers hold investment risk rather than customers.[185] In Japan the electricity sector is fully open to competition. Even small customers can choose who they buy their electricity from and select their electricity rate from a variety of options designed to meet their needs.[186,187] In practice, in many countries there tends to be "a mix of government-owned, government-regulated, and privately owned systems".[188]

The structure of the power market determines incentives for rolling out energy efficiency. Brian Dean, Head of Energy Efficiency and Cooling, Sustainable Energy for All, suggests that "it is common in many countries for utilities to be focused on building more power plants and governments to be focused on reduction of demand, but there are benefits for utilities, governments and societies at large for efficient cooling. Reduced peak energy for cooling can increase utility profits, deliver governments' sustainable development goals and bring comfort, health and nutrition to people."

Consumers can save money on their energy bills

Unless electricity is state-subsidised, the costs are passed on to consumers in their electricity bill. In regulated markets, the utilities set electricity rates to recover the costs of investments. They lobby the regulator to build capacity and then pass the cost on to the consumer. This can result in high electricity prices: in the US in the 1970s, the regulated market structure and oil crisis of 1973 resulted in real electricity prices increasing by 40% between 1970 and 1980.[189]

These dynamics apply to efficient cooling: if no action is taken, the US$4.6trn needed to meet electricity demand from space cooling out to 2030 could be passed on to consumers. More efficient cooling could save up to $3.5trn, or 75%, of these costs.

While demand-side response programmes can create savings for consumers who participate, they can increase costs for those who do not. If the utility decides to increase prices at peak times to shift demand, then only those households that have the capacity to adjust their demand can respond to it. According to an Australian Energy Market Commission study, "For some consumers on low incomes this could lead to financial distress, affecting their ability to pay their electricity retail bills."[190] If the overall costs of providing peak energy are reduced and passed on to consumers who are not taking part in the programme, then all consumers can benefit.

The challenge is that consumers are largely unaware of the cost savings they could make from buying a more efficient AC unit or designing a house well. Iain Campbell of the Rocky Mountain Institute explains that, in India, if you buy a more expensive, efficient AC unit and run it over typical consumer operating hours, you would spend half as much over the unit's lifetime than if you bought the cheapest, least-efficient AC.

Even if consumers are aware of the potential savings, many are unsure which products to choose. Without good labelling systems consumers cannot tell an efficient AC unit from an inefficient one. According to Eric Gibbs, Chief Policy & Analysis Officer at CLASP, "Consumers are very sensitive to upfront costs, and are aware of the benefits of more efficient products. The biggest challenge is how to clearly differentiate products based on efficiency and operating cost savings so that consumers can make informed purchasing decisions".

A household energy use survey run by IPSOS and CLASP in Indonesia found that energy savings are a top priority when purchasing new electrical appliances. However, Indonesia's product labelling is poor: despite implementing energy labelling for AC units in 2015, only 6.5% of consumers are aware of the energy label.

Policymakers can create jobs and protect consumers

Policymakers are responsible for protecting people against electricity price hikes. Our estimated financial costs will feed through to electricity bills, impacting even those consumers without AC. This trickle-down effect disproportionately impacts those with lower incomes, who could be prevented from using their ACs if electricity prices rise.

In markets with near or total government ownership, where the government subsidises electricity prices, policymakers can benefit from efficient cooling. Kristen Taddonio of the IGSD claims that, "it is such a shame when you have a national government running a national power utility and selling inefficient ACs that drive up peak demand, and require investment in more power infrastructure." In 2018, the Indonesian government paid the main provider US$1.63bn in subsidies.[191] Cooling efficiency programmes can lower energy costs, reducing the need for subsidies and saving the government money.

Benefits beyond the expected: Reducing balance of payments deficits

The power sector in Brazil generates over 80% of its electricity through renewable sources.[192] Brazil also imports electricity from other countries: in 2018, approximately 7% of electricity consumed was imported.[193]

While electricity imports enable the economy to meet energy demand, they also contribute to increased economic flows out of the country and worsen its balance of payments (BOP) position. When imports exceed exports, an economy can run a BOP deficit. A persistent deficit is unsustainable, indicating a build-up of external debt. The need to repay this debt creates a drag on economic growth and has implications for foreign exchange reserves and the strength of the currency. Brazil has been running a BOP deficit since 2008. In 2019, that deficit stood at almost 2.2% of GDP.[194] Brazil's imports of electricity contribute to this deficit, with the need for cooling adding to demand. AC accounts for 14% of electricity consumption in Brazil's residential sector.[195] With demand for AC units projected to grow at an average annual rate of 6.9% to 2030, our analysis estimates that demand for electricity for cooling could increase from 54 TWh in 2020 to 106 TWh in 2030. This growth threatens to place increased strain on the country's BOP position if imports of electricity rise to offset demand.

As policymakers pursue economic recovery in response to COVID-19, energy efficiency programmes can create jobs. They can be rolled out relatively quickly and easily, and the requirements are generally low – installing wall insulation requires less training, or retraining, than installing solar panels.[196]

As policymakers focus on net zero goals, they need to realise that efficient cooling can help them meet those goals more quickly and less expensively. Eric Gibbs of CLASP states that, "Policymakers need robust analysis and best practice policy guidance to assess the benefits of policy options, including GHG emissions reductions, avoided power generation capacity and related infrastructure investment, and energy savings at both the national and consumer level." Cost savings and employment opportunities are key benefits.

Power providers

Power outages cost utilities money. Efficient cooling minimises the risks of outages while also reducing the costs of peak demand. As Mark Radka, Chief of Energy and Climate Branch, United Nations Environment Programme (UNEP), states, there is "definitely a role for utilities: more and more AC is a peak-load headache for them".

Some power providers see opportunity in energy efficiency. Rolands Irklis, Chairman of the Latvia Public Utilities Commission, says that rising demand for electricity means there is opportunity for both expansion of the power sector and energy efficiency: "demand will still be growing but it does not have to be inefficient, we have strong requirements for energy efficiency." Kristen Taddonio adds, "It depends on the utility but most utilities support energy efficiency programmes over distributed generation – where small generators pile onto the grid taking share from the utilities. Compared to distributed generation, they are more on board with energy efficiency."

But if regulation does not require providers to drive efficiency, most utilities prefer to run demand-side response programmes. These allow them to sell more electricity while also levelling out demand to avoid peak time costs. Brian Dean notes that, "Some utilities get it and others do not. The regulated ones are required by law to get it. Some see it as a threat to their business model, they focus on the fear of not selling an extra electron as opposed to the opportunity of reducing costs to increase profits."

One approach to get more power providers on board, is to combine energy efficiency programmes with demand-side response programmes. Natasha Vidangos, Vice President of the Alliance to Save Energy, notes that "utilities can be roughly divided into three groups: those who are really excited to research these opportunities, invest in them and roll out pilot projects; those who are taking a wait-and-see approach; and those who do not show any interest. If policymakers can encourage some power providers to make the move first, then others may see the benefits and follow suit." If policymakers can encourage some power providers to make the move first, then others may see the benefits and follow suit.

How to capture the benefits of efficient cooling

As demand for space cooling rises, the risk of power outages increases. If policymakers do nothing to improve the efficiency of cooling, it could result in costs of US$4.6trn and emissions of 10.1 GtCO_2 by 2030. Even a more ambitious shift to renewables will be costly, and these costs will be passed on to consumers. Efficient cooling can reduce these costs by up to 75%, equivalent to $3.5trn in financial cost savings and 7.6 GtCO_2 in environmental cost savings. It can also hasten the transition to net zero by up to eight years. This is in everyone's interests: climate change impacts human health and safety, livelihoods, food security, water supply and economic growth.[197] Delivering efficient cooling can contribute to limiting global temperature rises to 1.5°C.

While policymakers have the biggest role to play, consumers, the power sector, investors, NGOs, the media, and philanthropic and academic organisations can all drive efficient cooling.

What needs to happen?

Making efficient AC accessible. Countries must roll out the best available AC technologies through regulations and standards. Taking a regional approach will make this most effective. Mark Radka of UNEP states, "If you can get regions, such as ASEAN, to agree on efficiency regulations, then costs go down and problems with dumping and price competition become less of a problem."

Policymakers should follow the UNEP Model Regulation Guidelines, which provide "guidance for governments in developing and emerging economies that are considering a regulatory or legislative framework" for energy-efficient AC and refrigerating appliances.[198] These countries can also seek guidance from organisations such as CLASP and ASHRAE (an organisation of industry members that provides support on equipment standards). Policymakers can also support Energy Service Companies (ESCOs) that offer energy services to users with energy savings tied to the service delivery.[199] In addition to driving regulations, standards and innovation, policymakers must leverage technology and finance mechanisms to bring locally relevant, efficient cooling solutions to those who need it most.

The private sector, including investors, can invest in innovative technologies and programmes that continue to find new ways to improve efficiency. Multilateral Development Banks and International Financial Institutions can also provide technical and financial assistance to support the rollout of efficient equipment.

Educating consumers. Consumers need to know which AC units are the most suitable. As Iain Campbell of the Rocky Mountain Institute explains, "in many countries, the government does a huge disservice by letting citizens be duped by cheaper ACs that prove more expensive over their lifetime – the average consumer does not understand." People should be aware of the long-term cost savings of purchasing a more efficient AC unit. Labelling programmes are an effective way of providing information to consumers. According to Eric Gibbs from CLASP, "In India, where policymakers launched a mandatory labelling programme in 2009, awareness and understanding of efficiency labels is high – they are well recognized and valued by industry and consumers."

Consumers should also be educated about the need to maintain their equipment to keep it performing as efficiently as possible, as well as how to do this.

Leveraging wider cooling measures. As part of broader programmes to create jobs and improve livelihoods, policymakers can introduce wider measures that reduce the need for AC. These include voluntary green building codes.

At the local level, governments can run programmes like Saudi Arabia's Green Riyadh project to improve air quality and reduce temperatures.[200] Policymakers can also invest in training and prioritising opportunities for building and cooling efficiency as they launch further jobs recovery packages in response to COVID-19.

Incentivising the power sector. In regulated markets, the regulator can set energy efficiency targets for power providers and can tie energy efficiency savings into decisions when approving new power generation investment. Policymakers can advocate programmes that combine demand-side response, which power providers are enthusiastic for, with energy efficiency.

As use of renewables grows, the power sector needs to consider all options. To increase the potential for demand-side response programmes, it can use smart technology to help enrol residential users. It can also improve marketing messaging to consumers to make programmes easier to understand. Finally, improving data and analytics across the board will enable utilities to better state the benefits of participating in programmes and thereby help to convey their message.

Shifting to system-level thinking. To make net zero possible, all stakeholders need to take a systems-level approach focused on what energy-related service is required and how to provide it in the most cost- and emissions-effective way.[201] Stakeholders need to break down siloed thinking and work together. At the national level, through policies like national cooling action plans, policymakers can make cooling a cross-ministerial issue that brings actors together and cuts across sectors and programmes.

Methodology

As cooling demand grows – the result of accelerating climate change, urbanisation and income growth – increased pressure will be placed on the power sector to provide the electricity to meet this demand. In this report, we assess the implications of growth in cooling demand for electricity demand, and the resulting financial costs and emissions from electricity generation. Using an Excel-based modelling approach, developed after an extensive data audit and literature review, we estimate the potential gains from moving to more efficient, climate-friendly cooling solutions.

The model assesses the electricity generation and emissions which arise as a result of electricity demand for cooling under a range of scenarios including:

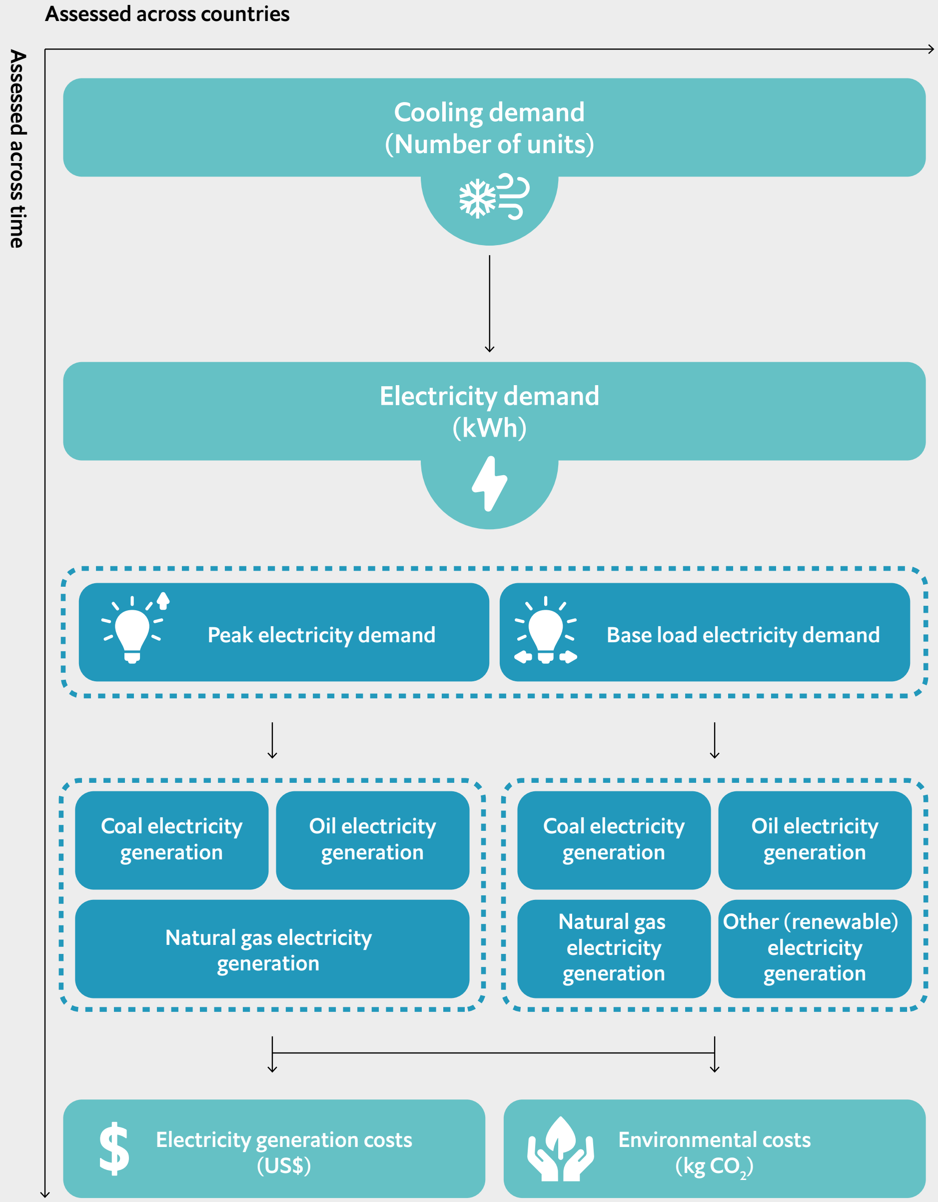
- **Baseline ("do-nothing") scenario.** The baseline scenario forecasts the growth in electricity demand based on forecasts of growth in cooling demand under the assumption that no changes are made to the current levels of cooling efficiency. In other words, electricity demand grows directly in line with growth in demand for cooling units.
- **Efficient cooling scenarios.** Efficient cooling scenarios assess the potential reduction in electricity demand per cooling unit either as a result of AC units becoming more energy-efficient, or as a result of a reduced need for mechanical cooling through improved building design and urban planning. Therefore, under the efficient cooling solution scenarios, electricity demand grows at a slower rate than growth in demand for cooling units.

The model forecasts the financial costs and emissions under the different scenarios up to 2030. The analysis is conducted at the country level for the following countries: China, the US, Japan, South Korea, India, Indonesia, Brazil, Mexico, Philippines and Vietnam. In addition, aggregated costs at the global level are estimated.

Baseline scenario

As a first step, we develop baseline forecasts for electricity demand and the associated financial costs and emissions using the approach discussed below.

Baseline scenario assessment



Source: EIU

1. Estimating cooling demand. To build baseline estimates of the costs associated with the growth in cooling demand, we use forecasts of demand for residential and commercial cooling units. IEA projections are used for growth in the stock of AC units for selected countries. The total stock of units is then split by residential and commercial AC units based on EIU analysis and data from P&S Intelligence which forecasts growth in sales across these two market segments.

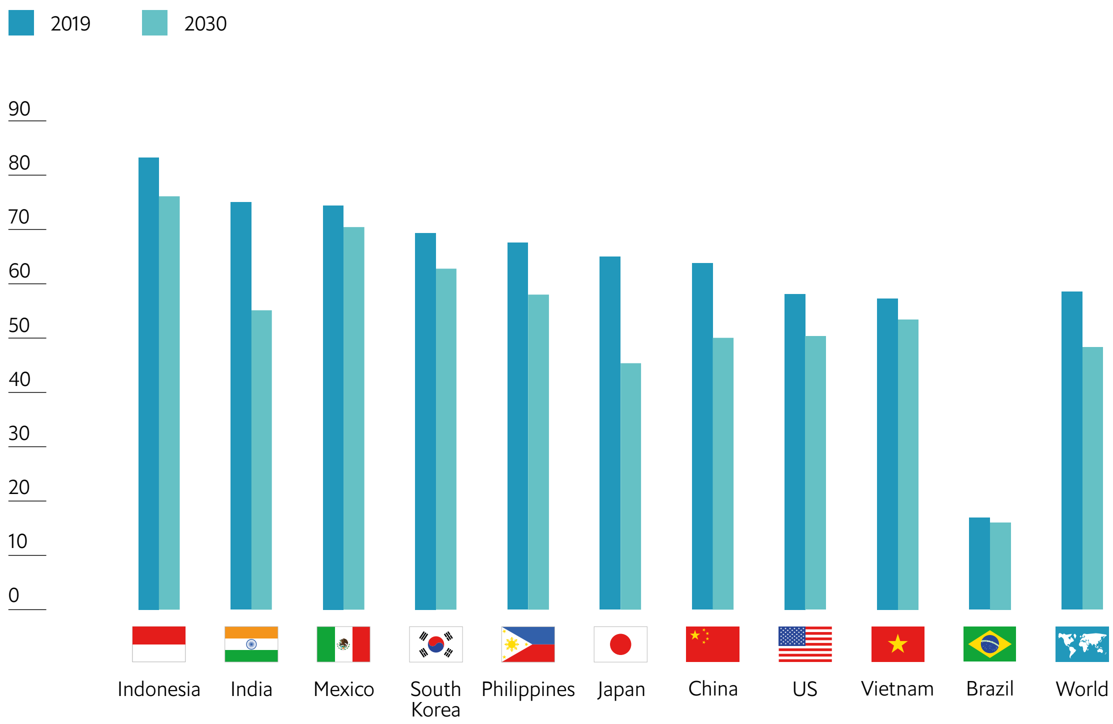
2. Estimating electricity demand for cooling. The electricity demand for cooling is estimated based on projections of growth in the stock of AC units and the annual average electricity consumption per unit.

To estimate the total electricity consumed by the projected stock of units, we use data on the unitary electricity consumption (UEC) of AC units which provides an average estimate of the electricity used by units in different countries based on the efficiency of cooling equipment and the hours for which they are used. UEC data for residential units is obtained from analysis produced by United4Efficiency, while data for commercial units is estimated based on the relative hours of use and capacity of commercial units vis-à-vis residential units.

The baseline analysis assumes that the average electricity consumption per AC unit remains constant over time in each country. Hence, total electricity demand is driven entirely by growth in demand for cooling units. The analysis also accounts for the potential losses incurred in the transmission and distribution of electricity, which results in higher electricity generation requirements to meet electricity demand. Data on losses by country is obtained from the World Bank.

Further, to account for differences in the costs and emission intensities, the total estimated electricity demand for cooling is split by peak and baseload demand and by fuel source. The peak load for cooling is estimated based on EIU analysis of the total peak load by country and IEA data on the share of cooling in peak electricity demand. Any remaining electricity demand for cooling after accounting for peak demand is assumed to be met by baseload electricity. Fuel sources used to generate electricity are assessed separately for peak and baseload demand. For peak demand, all electricity is assumed to be produced using fossil fuel sources (oil, coal and natural gas). For baseload demand, the split of fuel sources for electricity generation for cooling is assumed to be the same as the split for total electricity generation in each country. EIU data is used for the split of electricity generation by fuel source across fossil fuels and other renewable forms of energy, accounting for changes in the fuel mix across countries over time.

Share of fossil fuels in total fuel mix by country (2019 and 2030, % of total fuel generation)



Source: EIU data and analysis

3. Estimating financial costs of electricity generation for cooling.
The financial cost incurred in generating electricity to meet cooling demand is estimated based on the cost of electricity generation by fuel type across countries.

Data on the levelised cost of electricity (LCOE), which provides an estimate of the cost of each unit of electricity generated, is obtained both across different fuel types and across countries from the IEA. LCOE data accounts for both fixed and variable costs associated with operating a power plant. Therefore, it captures the requirements to build additional power stations and to expand the capacity of existing stations in order to meet demand.

The estimated LCOE across different fuel types in each country is applied to the previous estimates of electricity generation requirements for cooling to obtain an aggregate estimate of the total cost of electricity generation. The higher cost of electricity generation using fossil fuel sources compared to renewable energy sources is reflected in higher costs to meet peak electricity demand.

4. Estimating emissions from electricity generation for cooling. The emissions from generating electricity for cooling are proxied by indirect CO_2 emissions.

We use EIU data on the emission intensity of electricity generation by fuel source in each country to estimate total CO_2 emissions. Over time, changes in the emissions from electricity generation for cooling are reflective of both growth in electricity demand which increases emissions and changes in the fuel mix towards more renewable fuel sources which decreases emissions. In the baseline, the former exceeds the latter and, therefore, total indirect emissions from cooling at the global level are projected to grow.

Efficient cooling scenarios

We use scenario analysis to assess the impact of climate-friendly cooling solutions on demand for electricity for cooling, and the resulting impacts on the financial costs and emissions associated with electricity generation. Two types of scenario are assessed, as discussed below.

1. Making AC units more energy-efficient. One potential way to reduce the total electricity demand for cooling is to make AC units more efficient such that each unit requires less electricity to generate the same level of cooling. The impact of solutions which improve the efficiency of AC units is assessed by adjusting the UEC and estimating the impact on total electricity demand, holding cooling demand constant.

2. Reducing the need for mechanical cooling through improving building design and urban planning. In addition to making AC more energy-efficient, electricity demand for cooling can be reduced by minimising the need for mechanical cooling. In our model, this is assessed by adjusting the total estimated electricity demand for cooling. In reality, this could be achieved either through a reduction in the demand for cooling units, or through a reduction in the average UEC as the number of hours of use decreases.

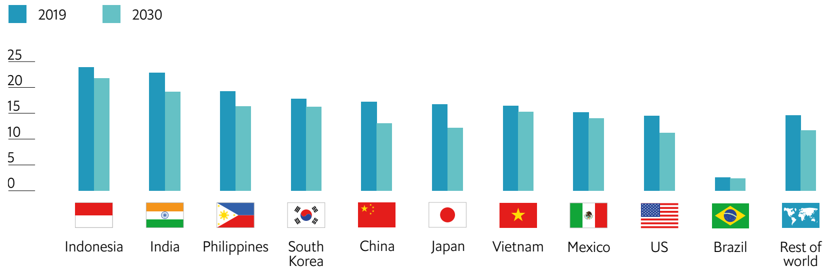
A comparison of the costs in the baseline scenario compared with the efficient cooling scenarios provides an estimate of the financial and environmental gains from the solutions described.

The EIU notes the static nature of the modelling approach which treats certain parameters as exogenous. For example, the changes in the energy mix over time in each country are taken as given. However, in reality, changes may be endogenous and affected by variation in total electricity demand as demand for cooling changes, and the associated price adjustments. Further research could explore the use of dynamic power system modelling to capture endogenous changes driven by cooling efficiencies.

Furthermore, the current research focuses on the benefits arising from energy-efficient cooling solutions in the form of reduced costs. Additional research might also explore the economic gains through multiplier effects from the cost reductions. As an example, reduced energy generation costs could benefit both power suppliers and consumers, with knock-on benefits for the economy through increased expenditure. Alternative modelling approaches could be used to estimate the wider economic benefits of the cooling solutions discussed in this report including Input-Output (IO) models and Computable General Equilibrium (CGE) models, among others.

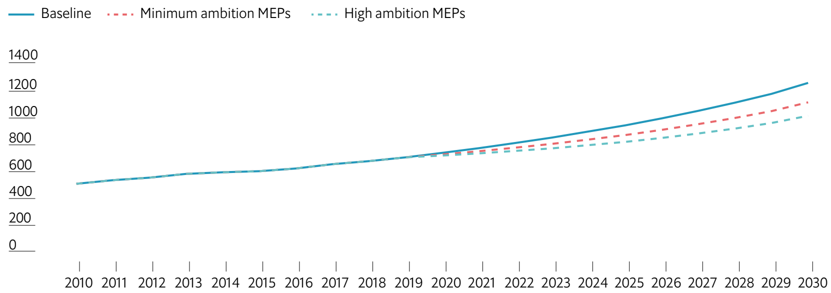
Appendix

Average emission intensity by country/region (2019 and 2030, g CO_2/ kWh)



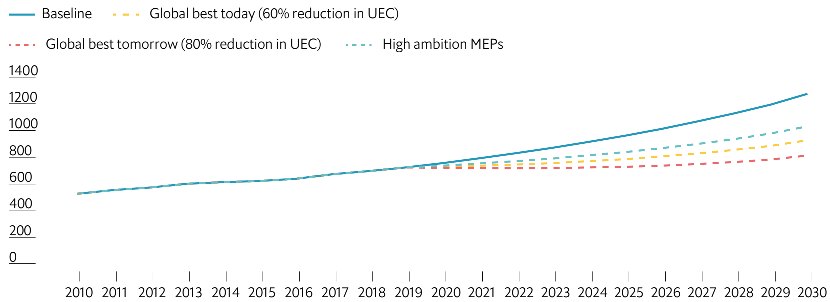
Source: EIU data and analysis

Global indirect CO_2 emissions for space cooling under alternative scenarios from implementing MEP standards ($MtCO_2$)



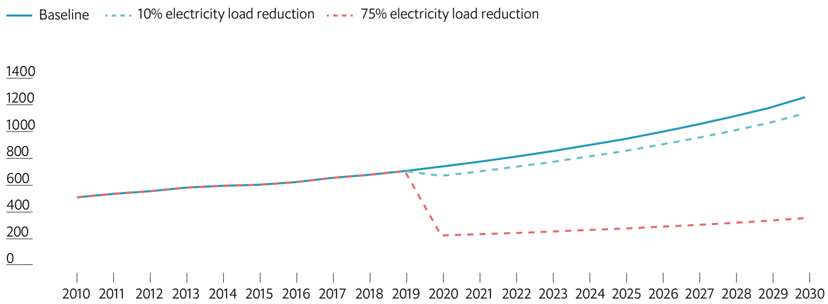
Source: EIU analysis based on multiple sources

Global indirect CO_2 emissions for space cooling under alternative scenarios from direct improvements to AC units ($MtCO_2$)



Source: EIU analysis based on multiple sources

Global indirect CO_2 emissions for space cooling under alternative scenarios from implementing measures to reduce electricity consumption ($MtCO_2$)



Source: EIU analysis based on multiple sources

Savings under a more ambitious shift to renewables

Measure	Financial cost savings to 2030[202]	Environmental emission savings to 2030
Standards (high-ambition MEP standards)	**17%** (equivalent to US$760bn)	**20%** (equivalent to 1,990 $MtCO_2$)
Best available technology today	**21%** (equivalent to US$980bn)	**24%** (equivalent to 2,470 $MtCO_2$)
Best available technology tomorrow (Rocky Mountain Cooling Prize solutions with 80% efficiency improvements)	**27%** (equivalent to US$1,270bn)	**30%** (equivalent to 3,020 $MtCO_2$)
Reduce the need for mechanical cooling (by up to 75%)	**76%** (equivalent to US$3,490bn)	**77%** (equivalent to 7,810 $MtCO_2$)

Source: EIU analysis based on multiple sources

Endnotes

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5. https://www.energy-transitions.org/wp-content/uploads/2020/09/Making-Mission-Possible-Full-Report.pdf
6. Furthermore, limiting warming to 1.5°C requires significant reductions in non-CO2 emissions, including methane, black carbon, and hydrofluorocarbons, as described at: https://www.ipcc.ch/sr15/chapter/spm/
7. The focus of this report is space cooling only – in other words, residential and commercial AC systems, including packaged and split units, chillers and other large space cooling systems. It does not focus on other types of AC or refrigeration.
8. This figure accounts only for indirect emissions in generating electricity for cooling and not direct emissions from refrigerants.
9. While peak demand hours vary significantly across countries and time of year, it is assumed that six hours of electricity consumption each day relates to peak demand.
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28. Measured based on projected growth in demand for residential and commercial AC units between 2020 and 2030 and average electricity consumption by AC units in each market. These estimates do not include additional electricity demand driven by building electrification initiatives.
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76. While peak demand hours vary significantly across countries and time of year, it is assumed that six hours of electricity consumption each day relates to peak demand.
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