CLIMATE ACTION PATHWAY

Net-Zero Cooling

Executive Summary

VISION STATEMENT

Cooling is critical for health, prosperity, and the environment. It keeps our vaccines safe and food fresh, ensures we have comfortable buildings to live and work in, and is central to our industrial and transport infrastructure. However, cooling is typically energy intensive and highly polluting due to the emissions from the electricity that powers this equipment (generated mostly from carbon intensive sources) and the refrigerants and insulation foam gas used in it (especially if not properly recovered and recycled). Cooling accounts for more than 7% of global greenhouse gas (GHG) emissions and these emissions are increasing rapidly.[1] We urgently need to cut these emissions and meet increasing demand for future cooling sustainably. The Kigali Amendment to the Montreal Protocol, which has already been ratified by over 100 countries, and regional frameworks such as the EU F-Gas Regulation, demonstrate how refrigerant emissions can be reduced,[2] however further refrigerant phase downs and out are needed. Meeting future cooling needs sustainably can reduce the costs of renewable energy build out by up to $3.5 trillion by 2030[3] and accelerate the net-zero transition by up to eight years.[4]

Our vision is that by 2050, there will be net-zero cooling for all through a focus on three impact areas:

- **Passive cooling:** Widespread adoption of measures that avoid or reduce the need for mechanical cooling including reductions in cooling loads, smart and human centric design and urban planning;
- **Super-efficient equipment and appliances:** A 'race to the top' S-curve transformation where the norm is super-efficient cooling equipment and appliances powered by zero carbon energy;
- **Ultra-low global warming potential (GWP) refrigerants and insulation foam gases:** Market domination of ultra-low (<5 GWP[5]) refrigerants across all cooling sectors and applications.

The net-zero cooling[6] transition will account for different climatic conditions in geographical regions and the different refrigerant needs of sectors. It will also account for the 'life and death' nature of the need for cooling, especially as the planet warms and the most vulnerable people require cooling for protection. Whilst it will be possible to significantly reduce energy use for cooling through passive measures and super-efficient equipment, it will remain essential to decarbonise the global residual energy supply and drive system flexibility. Efficient cooling will contribute to reducing the cost, increasing the speed of this transition and managing peak demand (which air conditioners often affect due to when they operate). This will include S-curve transformations and diffusions of net-zero cooling solutions across regions and applications.

By 2050, **passive cooling** will feature in every building with optimised passive solutions in new buildings. Passive cooling measures will range from shading, glazing, thermal mass and cool roofs to ventilation, green walls and roofs, and evaporative and radiative cooling. These measures will be optimised and

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[1] https://k-cep.org/wp-content/uploads/2018/03/Optimization-Monitoring-Maintenance-of-Cooling-Technology-v2-subhead....pdf
[2] https://www.eea.europa.eu/publications/fluorinated-greenhouse-gases-2020
[3] This does not include costs of expanding transmission and distribution networks to meet cooling demand so the actual number will be higher.
[4] Economist Intelligence Unit (2020) *The Power of Efficient Cooling* https://eiuperspectives.economist.com/energy/power-efficient-cooling
[5] Recognising there are other pathways to get to net zero, a Cool Calculator is being developed for release in 2021 which allows users to develop their own pathways using a combination of measures including GWP reduction, leakage reduction and end of life management
[6] Net-zero cooling means reducing greenhouse gas (GHG) emissions from cooling during operational life of products (excluding resource extraction and manufacturing) to as close to zero as possible and any remaining GHG emissions would be balanced with an equivalent amount of carbon removal – for example, by restoring forests and through direct air capture and storage technology. Resource extraction and manufacturing are covered by related pathways on industry and circular economy so are not a focus here to avoid duplication.

integrated within the design phase of any building or urban plan in order to avoid or reduce the need for mechanical cooling. Passive solutions also apply beyond space cooling. By 2050 coatings, preservation and solar drying will be commonplace for perishable products (e.g. food, medicine) where they have a lower GHG footprint than conventional refrigeration.

By 2050, a 'race to the top' S-Curve transformation that makes **super-efficient equipment and appliances** dominate markets will build on efforts to set Minimum Energy Performance Standards (MEPS) for key cooling equipment and appliances such as air conditioners and refrigerators. Such MEPS will be set based on a robust methodology and take into consideration the total cost of ownership (least lifecycle cost) to ensure the broad uptake of such equipment. Policy and industry will have harmonised product performance ladders to progress to super-efficient equipment and appliances with GWP limits so that progress on efficiency and ultra-low GWP refrigerants go hand-in-hand while ensuring that they are addressed via appropriate policy measures. Lessons can be learned from regions where these approaches have already been successfully applied (e.g. Europe and Japan). By 2050, off-grid renewable energy powering super-efficient equipment and appliances will also be deployed to address needs in rural and off-grid environments. Different forms and hybrids of mechanical cooling – for example evaporative and solid-state cooling such as thermo-electric – will be commonly used alongside vapour compression where feasible. Innovative high efficiency urban cooling solutions such as district cooling will be widely deployed in high cooling density areas. Holistic system changes to meet cooling demands such as the use of thermal sources (e.g. heat sinks, waste heat/cold and free cooling), thermal energy storage, and smart capabilities on super-efficient equipment and appliances, will be accelerated.

The next generation of production and infrastructure systems as well as business models will integrate smart cooling solutions. Cooling efficiency is key in electric vehicles and transport for refrigeration of products, air conditioning, cooling batteries, and for range extension. The smart integration of thermal storage, waste heat/cold (tri-generation, liquefied natural gas (LNG)) and electric grids in cities and industrial parks will be supported by integrated planning, design and co-location of facilities. By 2050, cooling will support the resilience of the energy system, including through the use of waste heat and cold and provision of flexibility through ice, liquid air and other solutions to help with energy storage and load shifting. The cooling sector will also be exploring the potential for greenhouse gas removals – for example by capturing CO_2 during the liquid air production process to help address residual emissions from cooling and potentially other sectors.

Incentives such as carbon pricing and subsidies (e.g. VAT reductions) will have initially powered this race but falling costs and more sustainable financial solutions, such as the ability to compete in supply side capacity markets, demand response opportunities, Cooling-as-a-Service (underpinned by circular economy principles), Pay-As-You-Save (PAYS), and smart credit systems such as property assessed clean energy programs (PACE) and utility energy efficiency programs, will catalyse equipment efficiency and mass market deployment. Existing cooling equipment will be run as efficiently as possible through optimised operation, control and maintenance.

By 2050 the market will have mainly adopted **ultra-low (<5) GWP** refrigerants and insulation foam gases and refrigerant emissions will be drastically reduced due to additional dedicated measures on leakage control, recovery, recycling, reclaim of refrigerants, treatment of emissions at end of life, and training. Action to phase down HFCs under an adjusted and more ambitious Kigali Amendment will be complemented by corporate, sub-national and financial actors, all committing to produce, consume and invest in ultra-low GWP refrigerants. Safety standards and buildings codes will be harmonised and adapted to safely and reliably allow the uptake of flammable refrigerants. The number of installers will have increased significantly and they will have the skills and knowledge to safely handle all refrigerants, prevent emissions and deal with more sophisticated technical solutions while also raising equipment and system efficiency. There will be no illegal trade in high GWP refrigerants or dumping of inefficient and high GWP refrigerant equipment and appliances that don't qualify in the exporting market.

The Multi-Lateral Fund (MLF) of the Montreal Protocol will continue to provide support but its funds will increasingly be made available for compliance with ultra-low GWP refrigerants while taking energy efficiency, safety, affordability and other relevant factors into account. Multi-lateral and bi-lateral development and climate finance targeting zero/low GWP efficient cooling will be systematically coordinated with MLF and other refrigerant transition funds to provide the finance needed to invest in ultra-low GWP refrigerant systems, super-efficient equipment and appliances and the scale up of passive cooling. Public and private financing institutions will develop and deploy new financing and de-risking instruments that facilitate access to capital markets and recycle private and public efficiency and productivity gains from cooling into innovation and investments, playing a key role in research and development and market building efforts. These efforts will be underpinned by performance rating and certification systems (such as EDGE), potentially allowing for commodification of performance and securitization of performance loans. Public and private finance will play a key role in research and development and market building efforts and will only flow to net-zero compatible cooling products and solutions (defined by regularly updated product lists/standards).

All three impact areas are needed to get to net-zero. The impact of net-zero cooling will be robustly, holistically and consistently calculated using 'lifecycle climate performance' and will aim to achieve the best lifecycle performance. Better data and evidence will exist about the costs, benefits and applicability of passive measures from key actors (e.g. building associations). **Achieving net-zero cooling for all through these three impact areas (passive cooling[7], super-efficient equipment and appliances, and ultra-low GWP refrigerants) will complement other climate action pathways** such as human settlements, transport, energy, and resilience. This will bring multiple societal and economic benefits (see facts and figures section below), many related to achieving several of the Sustainable Development Goals (SDGs), including: business and job creation opportunities; preventing heat related deaths; protecting and increasing productivity; enabling the energy transition; improving air quality by reducing coal fired power output; catalysing better building design; improving the resilience of food and medicine supply chains; improving the range of electric vehicles; and improving access to cooling.

In addition to helping deliver the SDGs in the decade ahead and through to 2050, net-zero cooling for all can help alleviate urgent pressures from Covid-19 such as: the need to keep medicines, vaccines and hospitals cool; thermal comfort for those sheltering in place; and keeping food fresh and nutritious in the face of supply chain and market disruption. By 2050, net-zero cooling for all will have simultaneously reduced up to 260 $GtCO_2$[8] emissions and enhanced access to much needed cooling as people across the world adapt to the changing climate.

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[7] Passive cooling includes measures that avoid or reduce the need for mechanical cooling including reducing cooling loads, smart and human centric design and urban planning

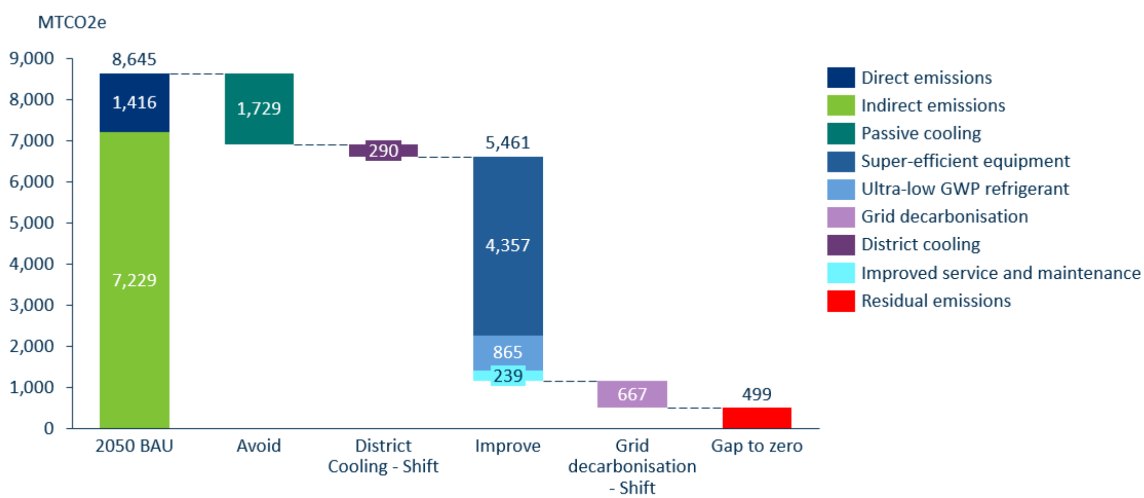
[8] United Nations Environment Programme and International Energy Agency (2020). Cooling Emissions and Policy Synthesis Report. UNEP, Nairobi and IEA, Paris. https://wedocs.unep.org/bitstream/handle/20.500.11822/33094/CoolRep.pdf?sequence=1&isAllowed=y

THEORY OF CHANGE

Net-zero cooling can be achieved through an 'avoid-shift-improve' approach applied to efficient equipment and appliances, powered by zero carbon energy, and using ultra-low GWP refrigerants. Additionally, passive solutions and behaviour change can help avoid and reduce the need for cooling while still meeting cooling needs. By applying the 'avoid-shift-improve' approach to each source of emissions from cooling, different solutions can be identified. These solutions have been aggregated in *Figure 1* (initial output) to show the relative contribution of each of 'avoid', 'shift' and 'improve' for domestic air conditioners (ACs), which is a significant component of overall cooling sector emissions.[9]

The '*avoid-shift-improve*' approach in *Figure 1* for domestic ACs is being modelled into an aggregate pathway to net-zero cooling. In practice there is no single pathway that covers every geography and sector but instead a collection of pathways to zero that are sensitive to specific conditions such as climate, infrastructure type and policy. For this reason, a 'Cool Calculator' is also being produced. This calculator supports mobilization of action to net-zero cooling by allowing stakeholders to make their own assumptions and to create their own pathways and S-curves.

Figure 1: Mitigation scenario for domestic AC as an initial output of the pathway to net-zero analysis[10]



This waterfall chart shows the emissions reduction achieved across the domestic AC sector using different mitigation approaches. It also displays the total offset amount needed in 2050 to achieve net zero cooling for all using the mitigation hierarchy verses a business-as-usual 2050 scenario.

Currently two cooling sub-sectors cause the largest amount of emissions – air conditioning and refrigeration – and each of these sub-sectors has four main applications – domestic, commercial, industrial, and mobile/transport. Pathways have been, and are being, developed to mitigate emissions in each of these sub-sectors and applications (see *Figure 1* as an example for domestic ACs).

[9] We aim to extend *Figure 1* to show the aggregate pathway covering relevant cooling sectors alongside the associated Cooling Action Table and Cool Calculator launch in early 2021

[10] These are initial outputs from the "Cool Calculator" tool which will be released in early 2021 alongside a supplementary evidence pack detailing calculations and assumptions. The tool will be open to users to make their own pathways to net zero using different mitigation options as presented in the figure.

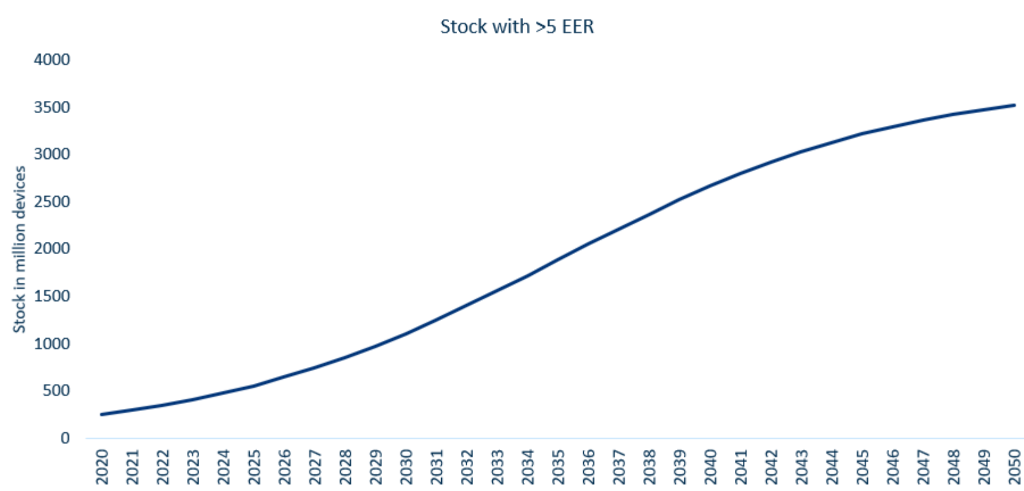
Ultra-low (<5) GWP refrigerants exist across nearly all sectors.[11] However, there are still significant barriers to their deployment such as building codes, safety concerns and a lack of skilled workforce. Some critical refrigeration needs (e.g. medical applications) do not yet have widely adopted ultra-low GWP solutions but they are a smaller share of overall refrigerant emissions.

High-efficiency cooling technology already exists across all sub-sectors but is not always widely available in all regions and purchase price can be a barrier (even though lifecycle costs are almost always lower as operating costs will typically be more than 75% of lifecycle costs). Refrigeration and air-conditioning are transitioning to high efficiency equipment and appliances[12] and the electricity mix is increasingly based on zero carbon energy sources. Some sectors are already using ultra-low GWP refrigerants. However, significant challenges remain to be addressed including higher upfront costs for super-efficient equipment, building codes restricting the use of flammable refrigerants and a lack of skilled personnel.

A diverse set of passive cooling and alternative (non-vapour compression) mechanical cooling solutions also exist, including evaporative, solid state, and ultra-low GWP refrigerant district cooling, and there are examples of their use across geographies and sectors. However, most of the world's buildings, cities, industry and transport have yet to deploy these solutions at scale. Behaviour change solutions also exist however gains and supporting evidence have been minimal. More rapid progress has been made on technological cooling solutions (see the facts and figures below on forecast air conditioning unit sales).

We have identified two impact areas where S-curve transformations are most likely: super-efficient equipment and appliances, and ultra-low GWP refrigerants. *Figures 2* and *3* below show S-curves for energy efficiency and ultra-low GWP refrigerants for domestic and commercial air conditioning. We note there is also potential for S-curve transformation on passive cooling and that there are important links between passive cooling and other pathways (e.g. Energy, Human Settlements, and Transport).

Figure 2: Indicative S-Curve for super-efficient domestic and commercial air conditioners showing global stock with an Energy Efficiency Ratio (EER) > 5 [13]

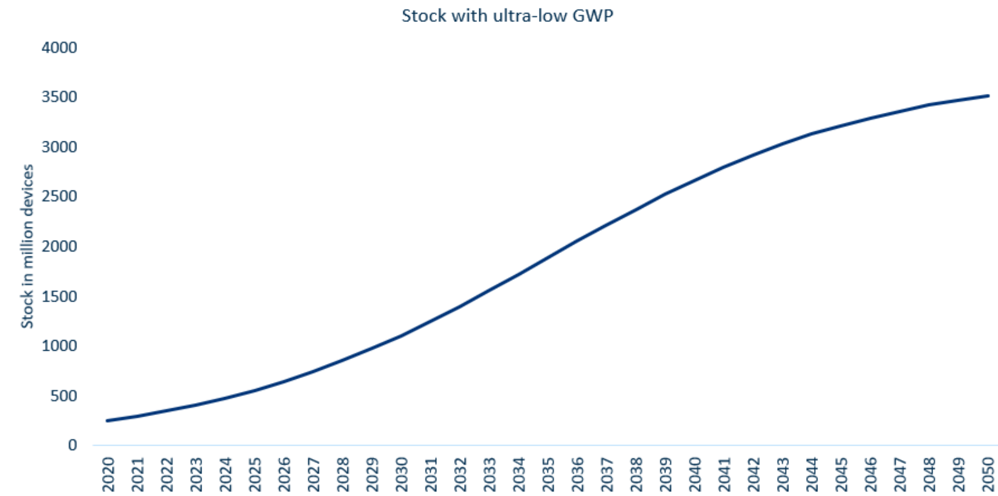


[11] An exception is medium sized split air-conditioning – this is too large for R-290 and needs either HFC-32 (which is A2L, lower flammability) or a non-flammable HFC-HFO blend.

[12] Further details on refrigerants specific to each cooling equipment type is detailed in the supplementary presentation

[13] EER has been used for the Cool Calculator but we recognise that regional SEER is a more appropriate metric for the purpose of establishing a common base.

Figure 3: Indicative S-Curve for ultra-low GWP refrigerants for domestic and commercial air conditioners



The S-curves will account for the current availability of stock which is super-efficient and uses ultra-low GWP refrigerants. As the starting points for super-efficiency and ultra-low GWP refrigerants may be different, we have shown separate S-curves and associated rate of progress to 2050. For example, there may be larger numbers of super-efficient cooling equipment and appliances in stock now than units using ultra-low GWP refrigerants so the S-curve for ultra-low GWP refrigerants starts slightly later and is steeper to account for this starting position. We recognise that optimising super-efficiency and ultra-low GWP refrigerants at the same time is likely to accelerate the timeframe and reduce costs and risk for achieving the pathway to zero on cooling.

MILESTONES TOWARDS 2050

Key milestones (outcomes) on the pathway to net-zero cooling for all are summarized in *Table 1* below. These are designed to fully implement the Paris Agreement, exceed the Kigali Amendment and contribute to the SDGs. The structure aligns with the framework in the corresponding Climate Action Table for cooling that outlines concrete actions for 2021, 2025, 2030 and 2040 in more detail.

Table 1: Milestones towards net-zero cooling by 2050[14]

Impact Area	By 2021	By 2025	By 2030	By 2040
Passive cooling	• Businesses, investors and cities make passive cooling commitments, including for certification and standards, as part of the Race to Zero • Covid-19 economic stimulus packages promote passive solutions • Governments include passive measures such as building regulations, new passive cooling for food technology demonstrations in their enhanced Nationally Determined Contributions (NDCs)	• Countries, cities and regions in largest cooling countries and regions (China, India, South East Asia, US, EU, MENA) have introduced passive cooling (including nature-based solutions) for human settlements and/or food focusing on new buildings being net-zero compatible by 2030 • Leading businesses, developers and investors commit to adopt and promote passive cooling measures • Largest cooling countries commit to decommissioning and recycling of all old cooling equipment	• All new buildings and urban areas incorporate passive cooling measures which are embedded in building codes • Passive cooling retrofit rates increased significantly to at least 3% per year • Businesses and investors financing passive cooling measures at large scale for human settlements and food • Behaviour change on passive measures the norm in majority of countries	• All possible existing buildings are retrofitted to passive cooling standards which are embedded in building codes • Access to passive cooling measures for all (including for transport and human settlements) • All old cooling equipment is decommissioned and recycled at end of life
Super-efficient equipment and appliances	• Champion countries commit to 'product performance ladders-labels-incentives' policies with inbuilt ratchets and GWP limits tied to best available technology and include cooling in NDCs • Leading cooling manufacturers commit to net zero cooling targets • The largest cooling equipment and appliance buyers in the largest cooling consuming sectors commit to net-zero cooling targets	• Enhanced product performance ladders - labels - incentives policies to drive energy efficiency gains in place in largest cooling countries and regions (China, India, South East Asia, US, EU, MENA)[15] • Leading investors use standards for super-efficient equipment and appliances when making finance decisions	• NDCs with commitments consistent with net-zero cooling path in place for 90% of the market • Large scale deployment of private sector investment and public procurement power for super-efficient equipment and appliances	• Enhanced product performance ladders-labels-incentives consistent with net-zero cooling are in place for all cooling technologies and regions • New technologies and business models make super-efficient equipment and appliances cheaper in most applications

[14] We welcome further quantitative estimates for these milestones and associated Cooling Action Table to help provide specific and measurable targets that progress can be monitored against.
[15] The enhanced product performance standards will need to include reference to both sensible and latent load performance.

	By 2021	By 2025	By 2030	By 2040
Ultra-low GWP refrigerants	• New commitments from leading countries on accelerated uptake of ultra-low GWP refrigerants beyond Kigali Amendment requirements • Significant replenishment of the MLF to support enhanced action and support accelerated activities to address the high growth rate of hydrofluorocarbons (HFCs) • The largest buyers in the largest cooling consuming sectors commit to only buy ultra-low GWP refrigerants	• Countries agree to adjust the Kigali Amendment phase down starting with sectors where earlier progress is easier (e.g. residential and commercial refrigeration) • Countries commit to addressing barriers to the uptake of ultra-low GWP refrigerants (e.g. products standards, building regulation and upskilling of service engineers) • Some applications can use only ultra-low GWP solutions (e.g. household refrigerators and freezers)	• All new cooling technologies for most applications have ultra-low or no GWP solutions provided barriers have been successfully addressed	• Full implementation of Kigali Amendment that phases down HFCs across all cooling sectors (emphasis shifts to compliance) • Most purchased appliances and equipment use ultra-low GWP refrigerants

In addition to the three key impact areas in *Table 1*, cross-cutting milestones include:

- **Resilience:** commitments on heat wave plans which over time cover 100% of the population in relevant cities and result in deaths from heat stress being as low as practically possible due to access to net-zero cooling; and
- **Maintenance and training:** training and skills programmes for building designers, installers and other cooling sector stakeholders to enable delivery of the milestones in each impact area.

PROGRESS

In cooling, good progress has been made on agreeing to phase down high GWP refrigerants in recent years and on introducing MEPS (73 countries have MEPS for room ACs[16]). However, the introduction of MEPS across all countries (and the phase out of high GWP gases) is still lagging as is the implementation and/or review of existing MEPS**.** Passive cooling, shifting to super-efficient equipment and appliances, and ultra-low GWP refrigerants are still at an early stage of deployment and need to be scaled up to deliver net-zero cooling for all.

Some passive measures have existed historically in vernacular construction or are becoming common – for example cool roofs – but most passive and nature-based solutions are not yet deployed at scale. This is despite the significant contribution passive cooling can make to getting to net zero cooling. For

[16] Energy Efficient Strategies and Maia Consulting report 'Energy Standards and labelling programs through the world in 2013' (May 2014)

example, the IEA notes that insulation, walls, roofs and windows can reduce energy needs for cooling between 10% and 40% in hot climates. Cool roofs can cut annual cooling energy use by up to 20%. Evaporative cooling systems for food refrigeration can reduce energy use by 70%.[17] Passive measures can generate significant cost savings for power generation of US$76 billion to US$570 billion and reduce 175 MtCO2 to 1,310 MtCO2 of emissions in 2030.[18] Stronger **policies** are needed with an initial focus on introducing passive measures for new buildings in building regulations. **Finance** is needed to deploy passive solutions but is held back by uncertainty of measurement and returns, an uncertain policy environment, limited awareness of passive solutions, and scarce examples of passive measures at large scale. The business case for implementing passive measures at a design stage that demonstrate long term cost benefits needs to be more visible. Investors can support accelerating the uptake of these measures by integrating passive measures requirements in building developments. New passive cooling **technologies** have significant potential. For example, radiative cooling solutions which dissipate heat to the sky by using new materials in panels with pumped fluids have shown 15% reductions in cooling energy use in early stage trials.[19] Innovation is also needed to adopt or rediscover local architectural practices and solutions that are appropriate to the climatic conditions and materials available in different regions. **Businesses** have an important role to play in demanding passive cooling measures and advising on passive measures (e.g. architects, engineers). **Civil society** is helping to highlight the potential for passive cooling measures and mobilise stronger policy, business and finance action on passive cooling.

Minimum energy performance standards for equipment and appliances need to translate into a 'race to the top'. For example, average air conditioner efficiency is around one third of best available technology installed and half of what is being sold in the market today. In the **policy** domain, most countries that have sizeable cooling loads have introduced MEPS which covered 85% of the air conditioners sold worldwide in 2016. 70 countries provide incentives for more efficient air conditioners. The United 4 Efficiency Model Regulation Guidelines provide voluntary guidance to assist Governments in developing and emerging economies that are considering a regulatory or legislative framework for minimum energy performance standards and energy labels.[20] Cooling has also been included by 11 countries in their NDCs and more are expected to do so by COP26 but the nature of these commitments varies. In the **technology** domain progress incudes five large cooling technology manufacturers setting targets to reduce emissions throughout the value chain by 2050 – Hitachi and Mitsubishi Electric are targeting an 80% reduction while Daikin Industries, Electrolux and Schneider Electric aim to achieve net-zero emissions.[21] Other companies are also making commitments to progress towards net zero. For example: Carrier is targeting carbon neutrality across its operations by 2030 and aiming to reduce its customers' carbon footprints by more than one gigaton;[22] Danfoss has committed to become CO2 neutral across its global operations by 2030;[23] Godrej & Boyce has signed up to the EP100 commitment

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[17] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3602570/. Note, these solutions do not always provide enough cooling to a low temperature.
[18] Economist Intelligence Unit report 'The Power of Efficient Cooling' (Nov 2020)
[19] SkyCool Systems, Using Sky Cooling to Increase Efficiency of Super Market Refrigeration Systems, https://www.skycoolsystems.com/case-study-grocery-outlet/
[20] https://united4efficiency.org/resources/model-regulation-guidelines/
[21] CDP (2020) *Playing it cool* *https://www.cdp.net/en/investor/sector-research/cooling-report* and https://www.futurenetzero.com/2020/10/07/schneider-electric-accelerates-its-commitments-for-carbon-neutrality-in-2040/
[22] https://www.corporate.carrier.com/corporate-responsibility/our-sustainability-goals/
[23] https://www.danfoss.com/en/about-danfoss/news/cf/danfoss-targets-co2-neutrality-latest-by-2030/

with an aim to achieve carbon neutrality by 2050; and Mabe has signed up to the EP100 commitment and has committed to completely phase out all HFCs from its refrigerator production plants by the end of 2020.[24]

On refrigerants, the Kigali Amendment is phasing down HFC refrigerants and foam gases. The Kigali Amendment and other **policies,** including the EU F-Gas Regulation (which mitigates F-gas emissions and includes sector specific GWP limits on equipment using F-gases) and the EU Mobile Air Conditioning Directive (which bans HFCs with a GWP above 150 in new vehicles), provide an important policy framework for action and the potential ratchet to deliver net-zero cooling for all by 2050. **Businesses, technologies, investors and civil society** all have a key role to play in supporting this enhanced ambition to ultra-low GWP refrigerants.

Planning and preparation at national and international levels will be key to achieve this. Governments are already working on **national cooling action plans** (NCAPs), which need to coordinate objectives and targets with policies, instruments and investments across all sectors relevant for cooling (e.g. India's cooling action plan). Increasingly, countries include cooling actions into their **NDCs** under the Paris Agreement, allowing for transparency of (public and private) expectations, international coordination of cooling actions and possibly access to climate finance and carbon markets. **Enhanced training** of cooling technicians at scale will be important to deploying and maintaining efficient cooling appliances, smart systems and new business models. A global **cool coalition** (led by the United Nations Environment Programme) already exists, and in India a domestic counterpart is being developed.

FACTS & FIGURES

- **Business and job creation opportunities:** The super-efficient cooling equipment market is already estimated to be worth US$135 billion and is set to grow dramatically due to rising temperatures, urbanization and income growth.[25] The Economist Intelligence Unit estimates that 4.8 billion new cooling equipment units will be sold globally between 2019 and 2030 and that the total market value will reach almost US$170bn in 2030. Delivering cooling for all may require up to 14 billion cooling appliances by 2050, up from around 3.5 billion today, creating significant new business and job opportunities.[26] Further businesses opportunity comes from the growth in innovative business models to finance and deploy this increased demand for clean and efficient cooling solutions.
- **Preventing heat related deaths:** 2.3 billion people could be both exposed and vulnerable to heat wave events by as early as 2030 and the World Health Organization forecasts that, by 2050, deaths from more extreme heat waves could reach 255,000 annually unless governments (primarily cities) adapt to the threat. Achieving net-zero cooling for all can play a key role in minimizing heat related deaths.

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[24] https://hydrocarbons21.com/articles/9380/mexican_fridge_maker_mabe_to_phase_out_hfcs_in_2020#:~:text=Mabe%2C%20a%20home%2Dappliance%20manufacturer,by%20the%20end%20of%202020.

[25] The Economist Intelligence Unit, 2019, The Cooling Imperative Forecasting the size and source of future cooling demand, https://www.k-cep.org/wp-content/uploads/2019/12/TheCoolingImperative2019.pdf

[26] https://www.birmingham.ac.uk/news/latest/2018/07/Global-quadrupling-cooling-appliances-14-billion-increase-energy-consumption.aspx

- **Protecting productivity:** Rising temperatures by 2050 could result in an annual 6% loss in gross domestic product (GDP) due to work hours lost from excessive heat in the worst affected regions[27] while increases in heat stress are projected to lead to global productivity losses equivalent to 80 million full-time jobs in the year 2030.[28] Net-zero cooling for all can help to avoid these significant productivity reductions.
- **Enabling the energy transition:** Net-zero cooling can accelerate the transition to zero carbon power generation at scale. A global transition towards the best cooling technologies for all new AC units could reduce total electricity demand by 25-33% in 2030, achieve cost reductions of US$260 billion and emissions reductions of up to 575 MtCO2. Doubling the energy efficiency of air conditioning by 2050 could save up to US$2.9 trillion in reduced generation, transmission and distribution costs alone and would reduce the need for 1,300 gigawatts (GW) of additional generation capacity to meet peak demand, the equivalent of all the coal-fired power generation capacity in China and India in 2018.[29] Over 100 GW of space cooling capacity in buildings was added in 2017, outpacing the record 94 GW of solar generation capacity additions that year.[30]
- **Improving air quality by reducing coal fired power output:** More than 60% of China's electricity is generated from coal, so energy used for cooling is a significant contributor to ambient (outdoor) air pollution. More than a million people die each year due to particulate emissions from power plants, cars and other sources. Net-zero cooling can help save lives by reducing this pollution.[31]
- **Delivering significant GHG emissions savings:** International Institute for Applied Systems Analysis (IIASA) researchers say that the combined effect of HFC phase-down, improvement of energy efficiency of stationary cooling technologies, and future changes in the electricity generation fuel mix would prevent between 411 and 631 billion tonnes CO2-equivalent of GHG emissions between 2018 and 2100, making a significant contribution towards keeping the global temperature rise below 2°C. Transitioning to high efficiency cooling could double the climate mitigation effects of the HFC phase-down under the Kigali Amendment, while also delivering economic, health, and development benefits. Their findings show that reduced electricity consumption could mean lower air pollution emissions in the power sector, estimated at about 5 to 10% for sulphur dioxide, 8 to 16% for nitrogen oxides (NOx), and 4 to 9% for fine particulate matter (PM2.5) emissions compared with a pre-Kigali baseline.
- **Catalysing better building design:** Building design influences whether occupants need air conditioners. 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 – to construction materials. One study estimates that controlling for windows design, size and orientation can reduce cooling loads by 30%. To date 28 cities have

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[27] ESMAP, 2020, Primer for space cooling *http://documents1.worldbank.org/curated/en/131281601358070522/pdf/Primer-for-Space-Cooling.pdf*

[28] International Labor Organization, 2019, Working on a Warmer Planet: The Impact of Heat Stress on Labour Productivity and Decent Work, Geneva, https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_711919.pdf

[29] United Nations Environment Programme and International Energy Agency (2020). Cooling Emissions and Policy Synthesis Report. UNEP, Nairobi and IEA, Paris. https://wedocs.unep.org/bitstream/handle/20.500.11822/33094/CoolRep.pdf?sequence=1&isAllowed=y

[30] Sachar, Campbell, Kalanki 2018 in United Nations Environment Programme and International Energy Agency (2020). Cooling Emissions and Policy Synthesis Report. https://wedocs.unep.org/bitstream/handle/20.500.11822/33094/CoolRep.pdf?sequence=1&isAllowed=y

[31] K-CEP 2018, Efficient, Clean cooling: a major near-term opportunity for China, https://www.k-cep.org/wp-content/uploads/2019/04/Efficient-Clean-Cooling-A-Major-Near-Term-Opportunity-for-China.pdf

signed the C40 Net Zero Carbon Buildings Declaration pledging to enact regulations and/or planning policy to ensure new buildings operate at net zero carbon by 2030 and all buildings by 2050.

- **Improving the range of electric vehicles (EVs):** When deciding to purchase an EV, many consumers worry about battery range – the distance the vehicle can travel in a single charge. Cooling requirements in EVs can reduce their range. The impacts are most significant in countries where ambient temperatures are high – above 25°C – as cooling requirements can reduce battery range by 17% and account for almost 45% of EV electricity requirements.[32]
- **Access to cooling:** Across 54 high-impact countries, 1.02 billion people among the rural and urban poor remain at high risk of lack of access to cooling in 2020. This includes 318 million people living in poor rural areas and 699 million living in poor urban areas. A further 2.2 billion lower-middle income people pose a different kind of risk: limited purchasing choices mean they are likely to favour cooling devices that are typically inefficient and could cause a dramatic rise in energy demand and associated emissions. In Africa, the rural poor population continues to grow, to 204 million in 2020, whereas in Asia, the number of urban poor continues to grow, up to 484 million people in 2020. The Cooling-as-a-Service initiative has around 40 business and investor partners who support the model in which building and business owners pay for the cooling service instead of investing in the infrastructure that delivers the cooling. This decreases the price of cooling access and therefore makes it more accessible for all.[33]
- **District cooling:** Countries and cities around the world are implementing district cooling systems to reduce primary energy consumption for cooling supply, phase-down HFC emissions and shift peak power demand particularly for commercial buildings (e.g. Paris, Barcelona, Abu Dhabi, Copenhagen, Stockholm, Thane, Singapore). Some of these cities are using cold water from lakes, rivers and the sea as a cooling source for their urban district cooling systems and as a way to reduce HFC emissions and electricity consumption for cooling. District cooling systems combined with thermal storage can save up to 50% of electricity consumption and reduce around 40 – 50% of GHG emissions compared to conventional individual cooling systems in areas of high cooling density.[34]

ENDS

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[33] Sustainable Energy for All *Chilling Prospects (2020)* available at: https://www.seforall.org/chilling-prospects-2020
[34] Sustainable Energy for All *District Energy in Cities Initiative* https://www.seforall.org/partners/district-energy-in-cities-initiative