SUSTAINABLE ENERGY FOR ALL

CHILLING PROSPECTS 2022

Chilling Prospects

TRACKING SUSTAINABLE COOLING FOR ALL

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SEforALL team members contributing to the report: Andrea Stojanov, Neil Claydon, Eyal Ben-Zwi, Jenny Nasser, Meriam Ottara, Tracey Crowe, and Sherry Kennedy.

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GLOBAL PANEL MEMBERS and ADVISORS:

Alan Miller, Climate Finance and Policy Consultant; Ana Maria Carreño, Senior Manager, CLASP; Andrea Voigt, Head of Global Public Affairs, Danfoss Climate Solutions; Daniel Magallon, Managing Director, Basel Agency for Sustainable Energy; Iain Campbell, Senior Fellow, Rocky Mountain Institute; Jennifer Layke, Global Director, Energy Program at World Resources Institute; Johannes Heister, Sr. Environmental Specialist, Sustainable Cooling, World Bank; Kurt Shickman Director, Extreme Heat Initiatives, Adrienne Arsht Rockefeller Foundation Resilience Center; Marcel Alers, Head of Energy, Infrastructure, Transport and Technology, UNDP; Mark Radka, Chief of Energy and Climate Branch, UNEP; Megumi Seki, Executive Secretary of the Ozone Secretariat; Nithya Ramanathan, CEO, Nexleaf Analytics; Pierre Jaboyedoff, Senior Engineer and Energy Consultant, BEEP India; Rajan Rawal, Executive Director, Centre for Advanced Research in Building Science and Energy, CEPT University; Tina Birmpili, Chief Officer, Multilateral Fund for the Implementation of the Montreal Protocol; Yi Jiang, Director, Building Energy Research Center of Tsinghua University, China.

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Thank you!

The Cooling for All Secretariat

Notes on all maps contained in this report: 1. The dotted line represents approximately the Line of Control in Jammu and Kashmir by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. 2. All maps were produced by SEforALL. They are based on the UN Map of the World, which can be found here: https://www.un.org/geospatial/content/map-world. The boundaries, colors, denominations and any other information shown on these maps do not imply, on the part of SEforALL, any judgment on the legal status of any territory or any endorsement or acceptance of such boundaries.

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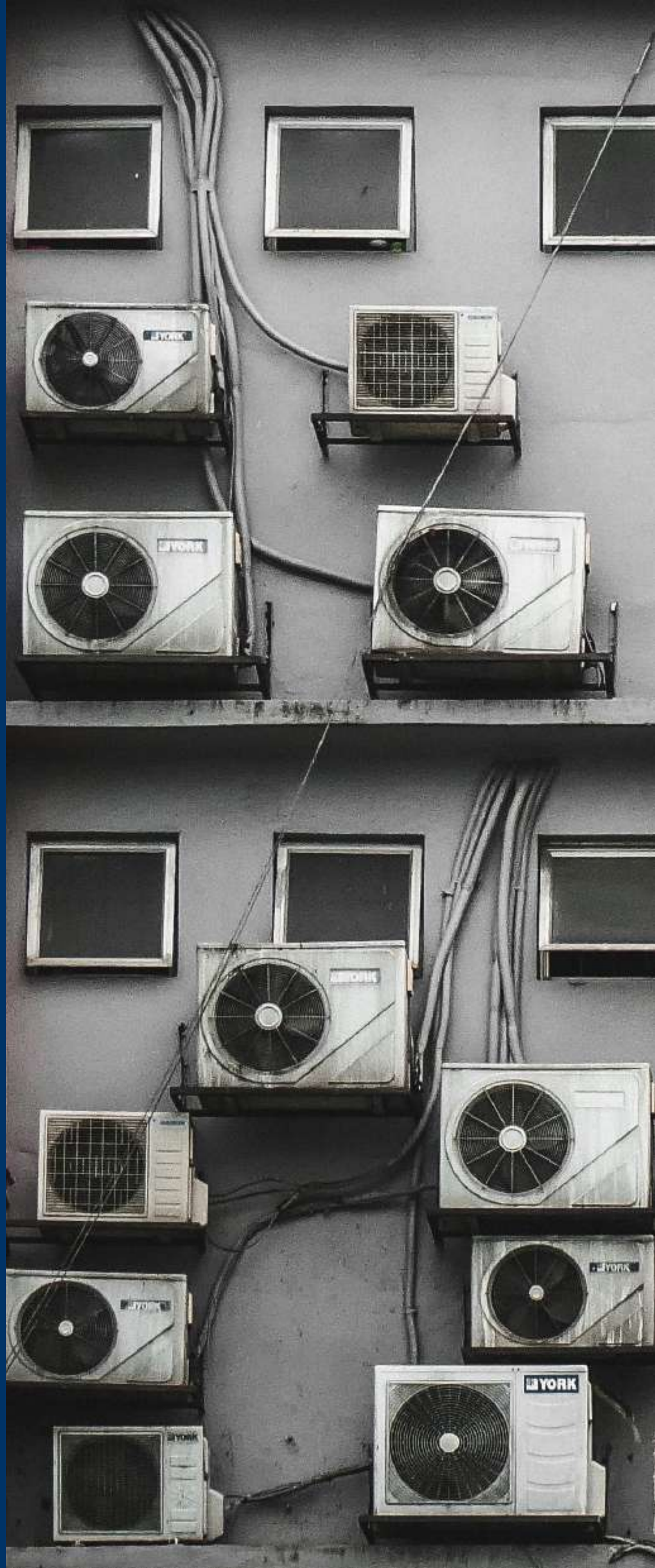

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EXECUTIVE SUMMARY

CHAPTER ONE: GLOBAL ACCESS TO COOLING GAPS AND 2030 SCENARIOS

Cooling is a make-or-break issue for the Sustainable Development Goals and the environment. With one in every seven people at risk from life-threatening temperatures or broken cold chains, neither people nor the planet can afford inaction on sustainable cooling.

DAMILOLA OGUNBIYI
CEO and Special Representative of the UN Secretary-General for SEforALL and Co-Chair of UN-Energy

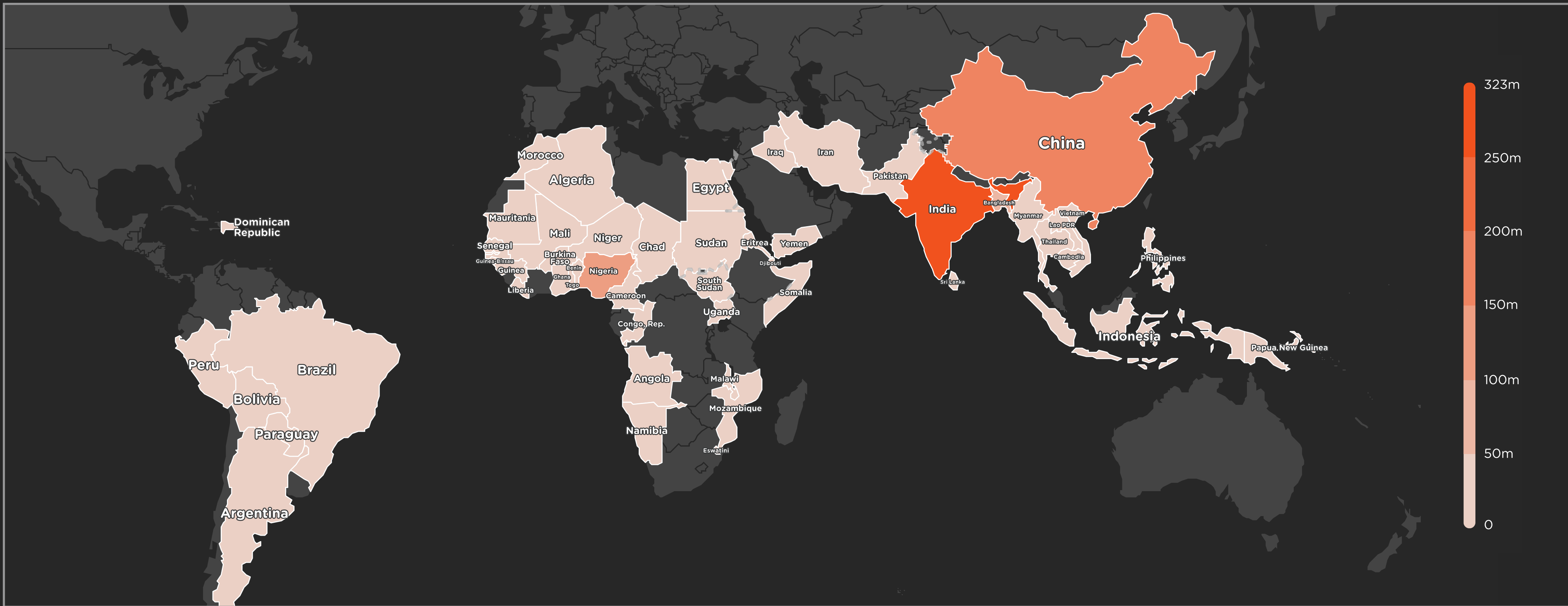
Chilling Prospects 2022 examines global cooling-access gaps among 54 high-impact countries and the high-temperature regions of 22 countries not considered high impact. It disaggregates between populations at high risk due to a lack of access to cooling (the rural and urban poor), those at medium risk (the lower-middle-income population) and those at low risk (the middle-income population). While most of the populations at high risk are in high-impact countries, efforts to leave no one behind must recognize where risk exists, even in countries not considered high impact.

Overall, across the 54 high-impact countries and 22 other countries, at least 3.66 billion people face high or medium risk from some type of cooling access challenge, an increase of 132 million people compared to 2021. A further 1.36 billion people are at low risk, but serious risks still exist from this population due to the climate and energy impacts where people choose ownership of cooling appliances that are not sustainable.

HIGH RISK: In 2022, across 54 high-impact countries and high-temperature regions of 22 countries not considered high-impact, 1.2 billion rural and urban poor are at high risk because they lack access to cooling. Of this figure, 1.17 billion live in high-impact countries. This represents an increase of more than 28 million people since 2021. The number of urban poor at high risk increased by 24.9 million people in high-impact countries, driven by a strong urbanization trend, while there was a reduction in urban poor at risk of 94,000 people in non-high-impact countries. The rural poor at high risk grew by nearly 4 million from 372.7 million to 376.6 million, with most of the increase in high-impact countries. This increase was driven by several factors, most notably the economic impact of the COVID-19 pandemic that continued to affect those living in extreme poverty in rural areas and cities, and urbanization driving further pressure on the urban poor.

In the Critical 9 countries, the number of people at high risk (rural and urban poor) grew by an average of 7 percent over the last year, with an increase in all countries except for Indonesia. India and China have the largest populations at high risk in absolute numbers (almost 323 million and 159 million, respectively), while Mozambique and Nigeria have the largest relative share of rural and urban poor among the Critical 9 countries, with 84 percent and 67 percent of the total population at high risk respectively.

FIGURE ES 1.1: POPULATION BY COUNTRY AT HIGH RISK DUE TO A LACK OF ACCESS TO COOLING



MEDIUM & LOW RISK: The lower-middle-income population at medium risk increased from 2.36 billion to 2.47 billion compared to last year, including an increase of 108.8 million among high-impact countries and a decrease of 5 million among non-high-impact countries. Income loss during the pandemic, in combination with other factors, brought the lower-middle-income population back to similar levels as in 2018, when the access to cooling tracking efforts began. Among this group, it is estimated that in 2021 an additional 165 million people globally lived on less that USD 5.50 per day because of the pandemic, 119 million of them in East and South Asia and the Pacific, 29 million in Africa and the Middle East, and 12 million in Latin America and the Caribbean.

At the same time, the middle-income population decreased by 76.7 million, from 1.44 billion to 1.36 billion in the 2022 analysis, a figure that includes a 75.7 million person decrease among the high-impact countries.

*For 54 high-impact countries and 22 countries not considered high impact)

Note: Dollar figures in this report refer to United States Dollars. Figures may not sum due to rounding.

TABLE ES 1.1: ANALYSIS OF RISK FROM A LACK OF ACCESS TO COOLING*

RISK SPECTRUM	HIGH RISK		MEDIUM RISK	LOW RISK
	• No access to electricity • Income below poverty line • Poor ventilation and construction • No access to refrigeration for food • Farmers lack access to cold chains • Vaccines exposed to high temperatures		• Access to electricity • Lower income levels • Ability to run a fan, buildings constructed to older standards • Food is refrigerated • Farmers only have access to intermittently reliable cold chains • Vaccines may have exposure to occasional high temperatures	• Full and reliable electricity • Middle income and higher • Well-built homes can include insulation, passive design, air conditioning • Food is refrigerated reliably • Farmers' goods and vaccines have well-controlled cold chains
RISK POPULATIONS	**RURAL POOR**	**URBAN POOR**	**LOWER-MIDDLE INCOME**	**MIDDLE INCOME**
RISK INDICATORS	• Lack of access to energy • Population living in rural areas on less than $1.90/day	• Lack of access to energy • Population living in urban slums on less than $1.90/day	• Population living on less than $10.01/day outside of rural or urban poverty	• Population living on between $10.01 and $20/day
2022 ACCESS GAP	**376.6 MILLION**	**821.5 MILLION**	**2.47 BILLION**	**1.36 BILLION**
2021 ACCESS GAP	**372.7 MILLION**	**796.7 MILLION**	**2.37 BILLION**	**1.44 BILLION**
CHANGE	**+3.9 MILLION**	**+24.8 MILLION**	**+103.8 MILLION**	**-76.7 MILLION**
FINDINGS & TRENDS	Despite steady electricity access improvements, risk-mitigating effects are outweighed by an increase in rural population that may not have access to, or be able to afford, adequate energy services for cooling	Urbanization, coupled with marginal electricity access, COVID-19 induced urban poverty, and effects of urban heat islands produce a consistently increasing risk	Pandemic-associated income loss, together with a dramatic increase of 165 million people globally living on less than $5.50/day contributed significantly to the increase	Increase in the number of people living on less than $20/day offset by a sharper increase in rural and urban poor as well as in lower-middle-income populations.
NOTES	• 1.2 billion people among the rural and urban poor are at high risk because they lack access to cooling. This includes 1.17 billion people in high-impact countries and 30.7 million people in non-high-impact countries. • The rural and urban poor increased by 28.6 million people in the 2022 analysis. This includes an increase of 28.8 million in high impact countries and a decrease in non-high impact countries. • The increase in those at high risk is driven by a 24.8 million increase among the urban poor			

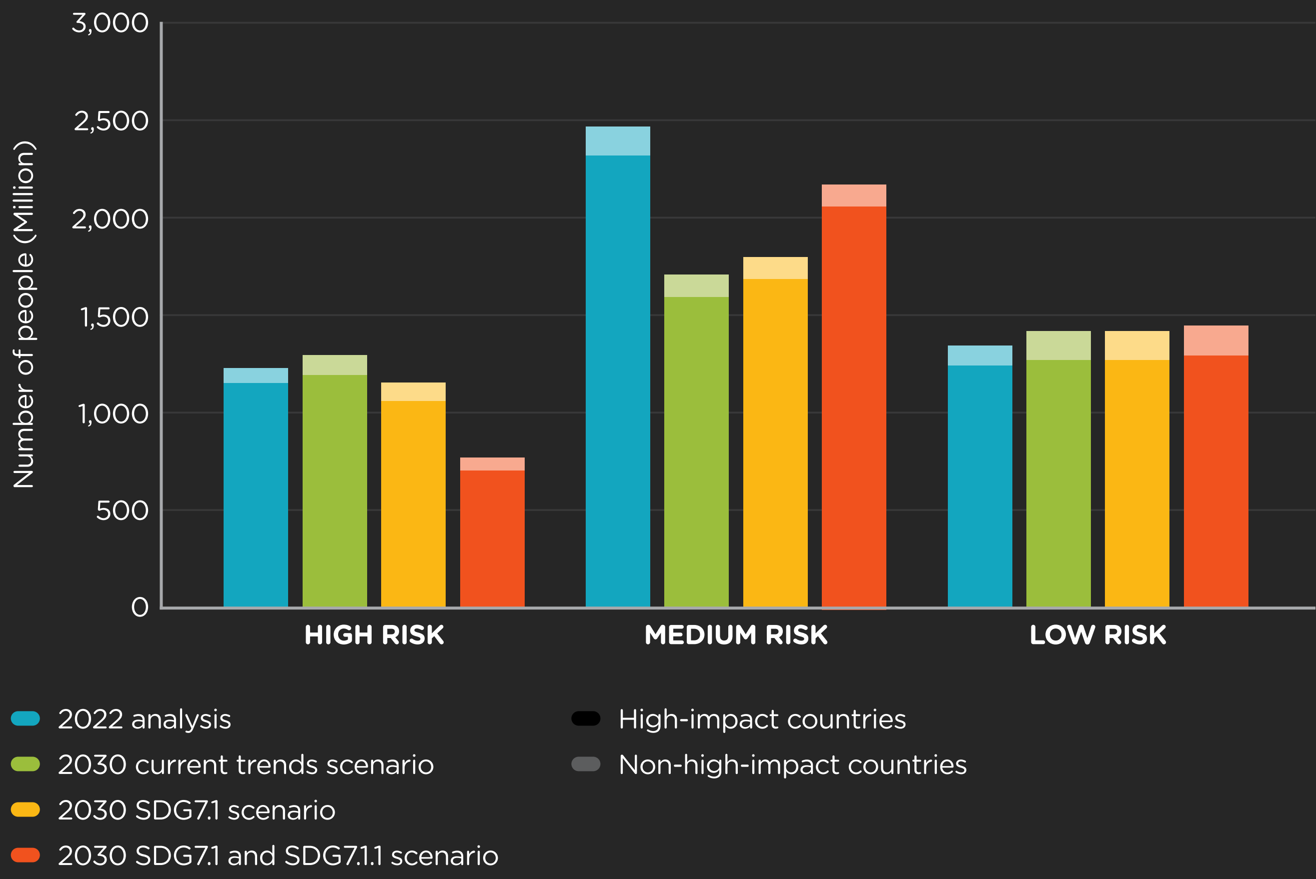
For the first time, Chilling Prospects 2022 forecasts scenarios for populations at risk through to 2030. As global temperatures increase, together with the urgency to mitigate and adapt to climate change, demand for cooling will have wide-ranging effects on sustainable development outcomes. In hot countries, delivery of SDG7 and the ability of populations to realize the benefits of equitable and just energy transitions will depend significantly on our ability to close cooling access gaps substantially by 2030.

HIGH RISK IN 2030: The scenarios show that across the 54 high-impact countries and high-temperature regions of other 22 countries, current trends would leave 1.22 billion people at high risk in 2030, compared to 1.2 billion in the 2022 analysis. This includes 1.18 billion people in high-impact countries and 43 million people in countries not considered high impact. If SDG7.1.1 and SDG1.1 are both achieved, the overall number of people at high risk decreases to 783.3 million — a 36 percent decline — including 745 million people in high-impact countries and 38.3 million people in countries not considered high impact. Over 90% of these would be concentrated among the urban poor, while the rural poor population would fall to below 50 million. To reduce the number of people at risk further and ensure equitable access to sustainable cooling, SDG7.2, SDG7.3 and SDG13 will all need to be achieved while ensuring affordability of solutions.

MEDIUM & LOW RISK IN 2030: The scenarios underscore that ensuring those at medium and low risk have access to affordable and sustainable cooling solutions is imperative for sustainable energy systems and climate goals. Under the current trends scenario, the lower-middle-income population (medium risk) will decrease to 1.72 billion people in 2030 across the 54 high-impact countries and high-temperature regions of 22 countries not considered high-impact. If SDG7.1.1 and SDG1.1 are achieved by 2030, faster reductions in extreme poverty lead to a slower decline in this population compared to current trends, although still resulting in a decrease compared to the 2022 analysis.

The middle-income (low-risk) population remains relatively stable under each scenario. If SDG7.1.1 and SDG1.1 are achieved, the middle-income population rises by approximately 95 million people compared to the 2022 analysis, to 1.46 billion in 2030.

FIGURE ES 1.2: POPULATIONS AT RISK ACROSS ALL COUNTRIES IN THREE SCENARIOS (2022 ANALYSIS AND 2030 PROJECTED)



CHAPTER TWO: SECTORAL DATA ACROSS KEY COOLING NEEDS

> *The data shows that business as usual means there will be more vulnerable people by 2030, making our efforts to deliver SDG 7 and the Paris Agreement more challenging. In a warming world, both equitable economies and just, inclusive clean energy transitions rely on rapidly delivering sustainable cooling for all.*

DAMILOLA OGUNBIYI
CEO and Special Representative of the UN Secretary-General for SEforALL and Co-Chair of UN-Energy

Access to sustainable cooling underpins the delivery of important components of Sustainable Development Goals 1, 2, 3, 7, 8, and 13, among others, and in partnership with the Cool Coalition, the World Bank ESMAP unit, and the University of Birmingham, among others have advocated for a needs-based approach to delivering access to cooling across three core needs that contribute to the SDGs: Food, Nutrition, and Agriculture, Health Services, and Human Comfort and Safety. This chapter provides an update for the community on new data related to these needs, as well as a general review of how action in these areas contributes to enhanced access to sustainable cooling solutions.

Food, Nutrition and Agriculture

The cost of food loss and waste is estimated at nearly USD 1 trillion annually. Food is lost and wasted throughout various stages of the food supply chain, with 14 percent of all food produced lost between harvest and retail, and 17 percent of all food produced wasted in households, restaurants and across other food services.[1,2] A 2018 study estimates that this figure will grow, with food loss and waste amounting to 2.1 billion tons of food annually, a global economic loss of USD 1.5 trillion in 2030 in a business-as-usual scenario.[3]

Food loss serves as an important indicator for levels of cooling access. Global trends show an average 3% annual increase in food loss from 2010 to 2019, with global total food loss (including non-perishables) in 2019 at a staggering 1.2 billion tonnes of food, equivalent to more than 3 times the food production of Africa annually. Among the 54 High Impact Countries for Access to Cooling, those in Asia have the highest food loss share at 48 percent, and food loss in low-income food deficit countries is about 22 percent of the total world food loss and has consistently increased over the past decade, widening the food supply gap for large sections of vulnerable populations.

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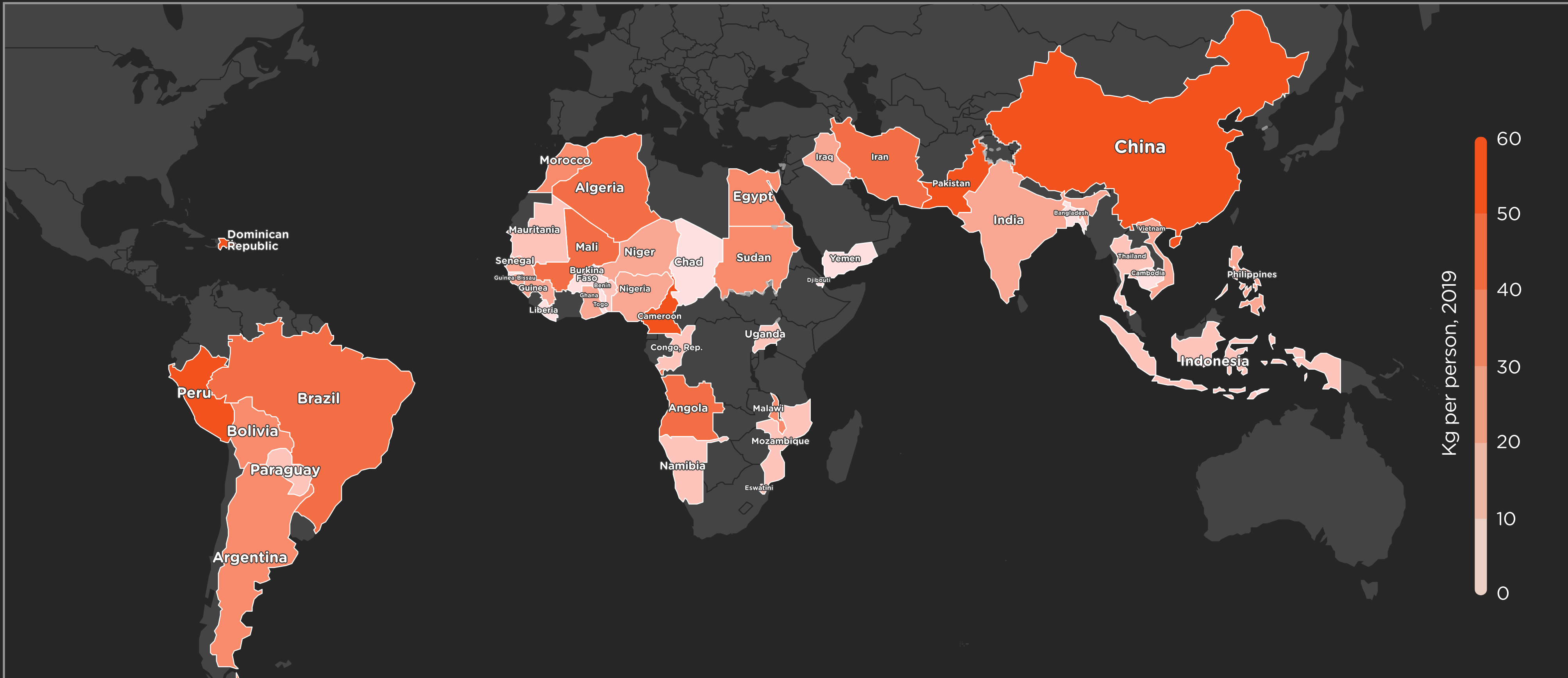
[1] FAO (2021). Transform food systems to avert $400 billion annually in loss and waste. Link.

[2] FAO (2014). Food Wastage Footprint: Full-cost Accounting. Final Report. Rome. Link.

[3] Boston Consulting Group (2018). Tackling the 1.6-Billion-Ton Food Loss and Waste Crisis. Link.

The impact of food loss on vulnerable populations is more evident when assessing the per-person food losses in high-impact countries. The average food loss is 35 kg per person per year and losses range between 3.8 kg to 62 kg per person in the 54 high-impact countries. Data show that Cameroon, China, the Dominican Republic, Pakistan and Peru are on the high end of that scale.

FIGURE ES 1.3: FOOD LOSSES PER PERSON IN HIGH-IMPACT COUNTRIES FOR ACCESS TO COOLING (KG/PER CAPITA)



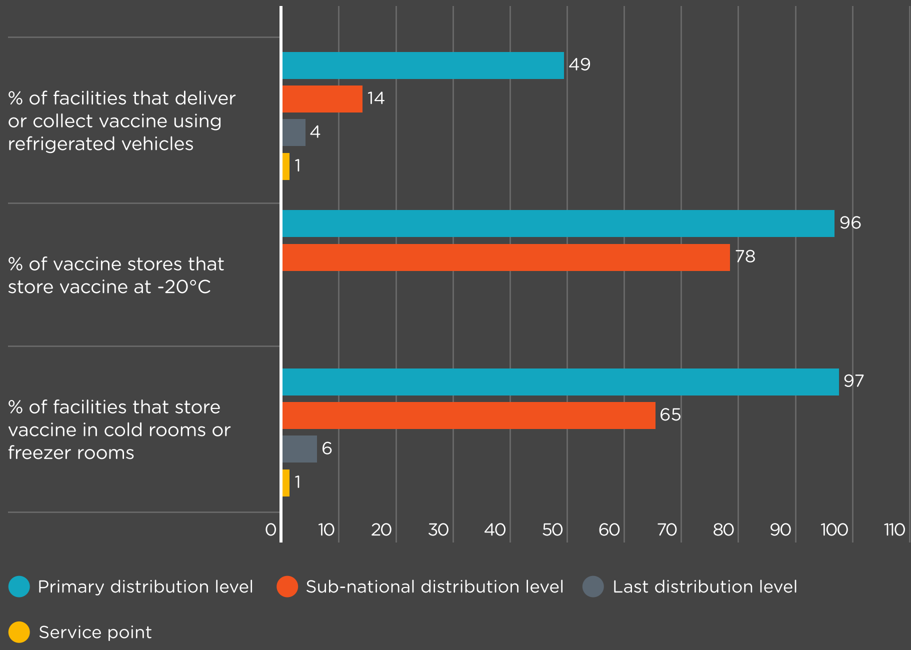
Source: SEforALL analysis of FAO data

The report also examines energy use and climate impact due to food production and loss and where improvements in energy use can support increased access to cooling. Closing cooling access gaps in the agricultural sector through cooling efficiency improvements, an expansion of sustainable energy technology, and Kigali-compliant refrigerants, could avoid 55 percent of food losses experienced now and reduce cold chain emissions by 55 percent.[4] Current energy use for food production in the 54 high impact countries for access to cooling is dominated by major emerging economies, notably China, Brazil, Argentina, and Egypt. The energy use in high impact countries for access to cooling from food production is highest in Asia, followed by South America and Africa. In Asia, 16 countries account for 78 percent of the energy use for food production, while in Africa 31 countries account for only 7% of energy use.

Health Services

The cooling needs in health services include cold chains that transport temperature-sensitive medical products, including vaccines which must typically have consistent cold storage between to 2°C and 8°C to maintain their efficacy. Outside COVID-19 vaccination efforts, immunization coverage rates are not keeping pace with population growth, with global coverage for the three-dose diphtheria-tetanus-pertussis vaccine falling from 86 percent to 83 percent, likely hampered by efforts to address the COVID-19 pandemic. The WHO's Effective Vaccine Management (EVM) updated assessment also confirmed that last mile facilities generally lack access to cooling and cold chain equipment, with no service points or local distribution in all 86 countries surveyed had storage facilities capable of maintaining temperatures of -20°C.

FIGURE ES 1.4: COLD CHAIN INDICATORS FOR 86 COUNTRIES



Source: WHO Effective Vaccine Management Assessment (2009-2020)

[4] Sarr, J et al. "The Carbon Footprint of the Cold Chain, 7th Informatory Note on Refrigeration and Food." IIR, 2021, Link.

In 2021, verification that vaccines from Pfizer BioNTech and Moderna can be stored at higher temperatures (between 2 and 8°C) for approximately 30 days compared to the initial Ultra Cold Chain (UCC) storage of -20°C to -70°C, as well as increasing in vaccine supply and efforts from UNICEF, GAVI, and the WHO among others have supported increased access to COVID-19 vaccines in countries with vaccine cold chain access gaps. Recent vaccine developments have made cold chains an essential component of the malaria response, with the RTS,S/AS01 (RTS,S) malaria vaccine (stored between 2 and 8°C) recommended for children in Sub-Saharan Africa. The vaccine was trialed with 2.3 million doses in 3 pilot countries, where the RTS,S vaccine resulted in a 30% reduction in deadly severe malaria, and saved 1 life for every 200 children vaccinated.

Energy access remains a key challenge in rural health centers for providing access to cooling. Nearly 59% of over 121,000 healthcare facilities analysed in 2018 in 46 low- and middle-income countries lack access to reliable electricity.[5] Passive solutions, dedicated interventions to guarantee electricity supply, and solar photovoltaic and battery storage are among the strategies shown to close electricity access and cooling access gaps in health settings.

Human Comfort and Safety

July 2021 was Earth's hottest month on record and a warming world is increasing the risks to human mental and physical health. In 2014, WHO released a study estimating that 12,000 people lose their lives annually due to extreme heat waves, a figure that could rise to 255,000 annually by 2050 without adaptation.[6] **New research for The Lancet has shown that the scale of the challenge is already much larger, with extreme heat causing the deaths of 356,000 people in 2019 alone.**[7] The scale of this impact, at an estimated 1.1°C of global warming, is likely to grow globally as temperatures continue to rise, posing significant risks for vulnerable groups. At between 2°C and 3°C of warming, 16 times as many people would be exposed to heat waves, rising to 36 times as many people at 4°C, causing severe risk of heat-related mortality.

Workers face high risks from heat. In 2018, an analysis in 30 countries found that approximately one in three individuals who are exposed to heat stress in their job experienced negative health effects,[8] and in 2020, 295 billion hours of potential work was lost. Unsurprisingly, the three Critical 9 countries in South Asia (Bangladesh, India and Pakistan) experienced losses two-and-a-half to three-times higher than the world average.[9]

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[5] Cronk R, Bartram J. Environmental conditions in health care facilities in low- and middle-income countries: Coverage and inequalities, *International Journal of Hygiene and Environmental Health*, Vol.221, Issue 3, 2018

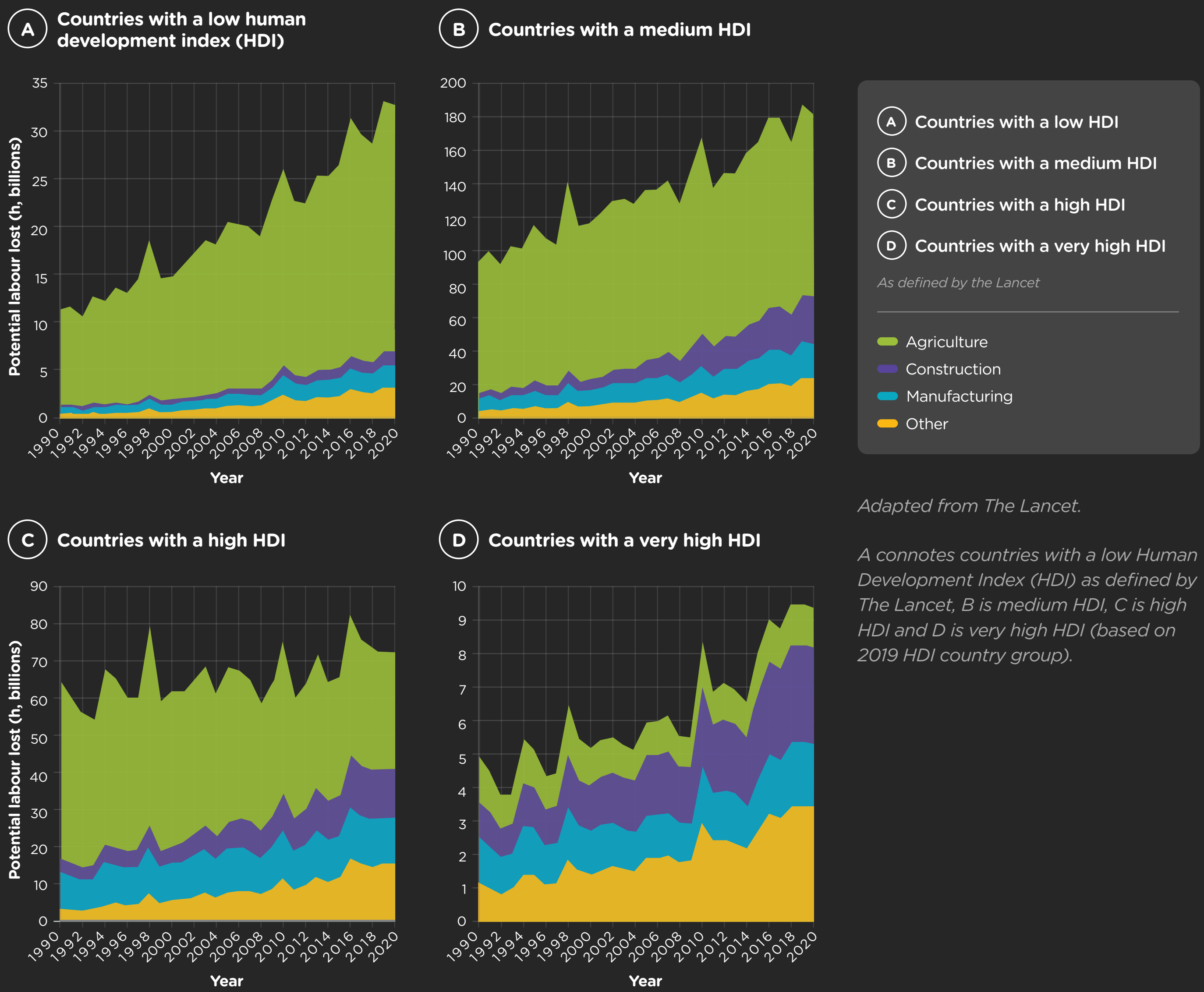
[6] WHO (2014). Quantitative Risk Assessment of the Effects of Climate Change on Selected Causes of Death, 2030s and 2050s. Link.

[7] Burkart, et al, Health in a World of Extreme Heat, The Lancet Vol 398, August 2021. Link.

[8] Flouris AD, Dinas PC, Ioannou LG, et al. Workers' health and productivity under occupational heat strain: a systematic review and meta-analysis. The Lancet Planetary Health 2018; 2: e521–31. Link.

[9] Romanello, Marina et al, The 2021 report of The Lancet Countdown on health and climate change: code red for a healthy future. The Lancet, Vol. 398, Issue 10311. 30 October 2021. Link.

FIGURE ES 1.5: POTENTIAL LABOUR LOST DUE TO HEAT-RELATED FACTORS IN SELECTED SECTORS (1990–2020)



Adapted from The Lancet.

A connotes countries with a low Human Development Index (HDI) as defined by The Lancet, B is medium HDI, C is high HDI and D is very high HDI (based on 2019 HDI country group).

In rural areas, extreme temperatures threaten many livestock and crops. Agricultural productivity growth in Africa has already seen a decline of 34 percent since 1961 due to climate change, more than any other region.[10] For poor rural populations, threats to agricultural livelihood assets risk triggering persistent poverty traps.

Human tolerance to heat has physiological limits. Higher average and extreme temperatures will cause these limits to be reached more regularly in the coming decades, especially in tropical regions.[11] Access to adequate cooling solutions will be fundamental, and demand for air-conditioning is expected to soar, driven by growing income levels and the need to adapt to global warming.[12] However, faster diffusion of inefficient units could lead to unintended consequences that include higher emissions, higher peak electricity demand, brown or blackouts, a more pronounced urban heat island effect, and heat inequities for those not able to afford air-conditioning.

As household incomes increase in developing countries, trends show that air conditioner, fan and refrigerator ownership also increases. In India, refrigerator ownership among low-income households is much higher than that of either fans or air conditioners, while fan ownership is much higher in both Brazil and Mexico.

Sustainable Cooling for Cities

Urban heat is driven by climate conditions, the topography of the land, the urban built environment, and waste heat, among other factors. The features of the urban environment are known to cause a higher temperature than their rural, or less developed, surroundings, typically referred to as the urban heat island.[13] The urban heat island effect (UHIE) can cause city temperatures to be 1°C to 4°C higher on average — often most pronounced overnight — with maximum temperature differentials of up to 10°C being observed. Exposure to extreme heat in urban settings has increased by almost 200 percent since the mid-1980s and is estimated to affect 1.7 billion people.[14] These urban heat conditions mean that urban populations can be at higher risk of heat exposure, with the poor and elderly being disproportionately affected.[15]

Heat exposure itself depends on conditions in urban areas of: (1) location characteristics, such as climate, weather conditions (including temperature, humidity and wind speed), topography, movement of air,

[10] Intergovernmental Panel on Climate Change, Sixth Assessment Report: Impacts, Adaptation and Vulnerability. 28 February 2022. Link.

[11] Ebi K. L. et al., 2021, P698-708, 21 August 2021. Link.

[12] IEA, 2018, The Future of Cooling, IEA, Paris. Link.

[13] Oke, T. R. (1973). City size and the urban heat island. Atmospheric Environment, 7(8), 769–779. https://doi.org/10.1016/0004-6981(73)90140-6

[14] Cascade, T., Kelly, C., Chris, F., Andrew, V., Stuart, S., Kathryn, G., Pete, P., & Tom, E. (2021). Global urban population exposure to extreme heat. Proceedings of the National Academy of Sciences, 118(41), e2024792118. https://doi.org/10.1073/pnas.2024792118

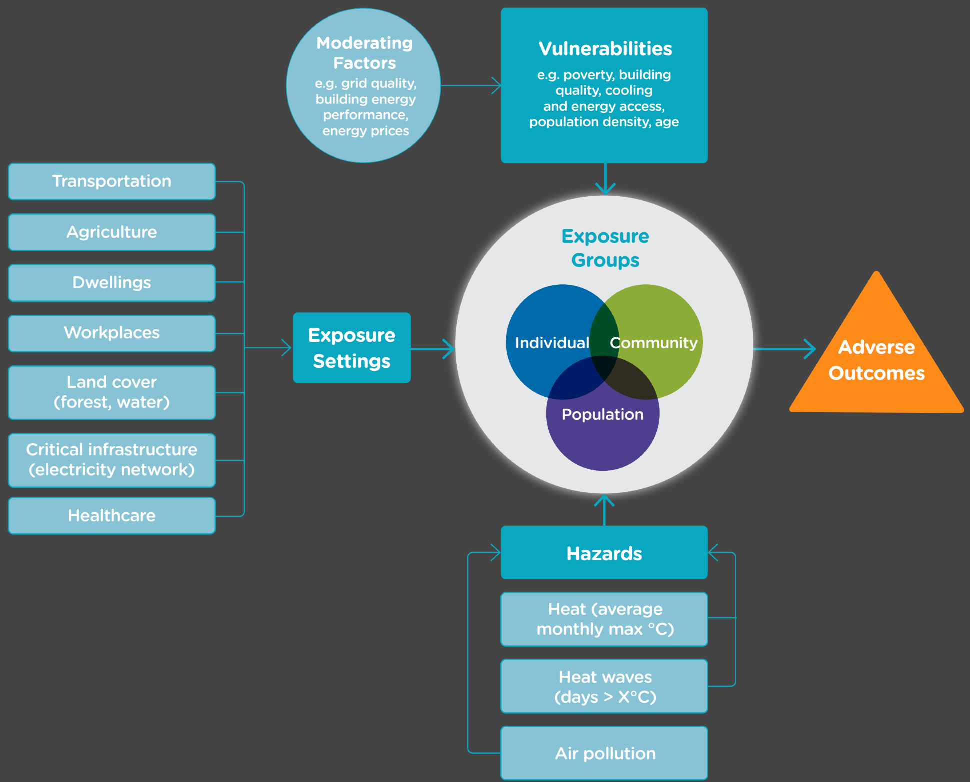
[15] Heaviside, C., Macintyre, H., & Vardoulakis, S. (2017). The Urban Heat Island: Implications for Health in a Changing Environment. Current Environmental Health Reports, 4(3), 296–305. https://doi.org/10.1007/s40572-017-0150-3

and the amount and type of natural surroundings of the city; (2) physical infrastructure, such as building and material choices for city design, access to electricity, availability of water- and nature-based infrastructure such as street tree canopies and vegetated/ forested areas; and (3) social infrastructure, such as health services and cooling alert systems.

As cities focus on addressing the implications of a changing climate and future population growth and the associated infrastructure and social services, alongside the form and function of the city, there is a need for toolkit approaches that provide an understanding of the risks being faced and their drivers, as well as strategies that aim to both mitigate and adapt to heat.

This chapter also provides an analysis of the impact of land-use change since 2015 in major cities in each of the Critical 9 countries and examines the implications of urbanization for urban heat. The annual global land-cover change maps[16] from the Copernicus Land Monitoring Service[17] form the basis of this analysis and the year-over-year land-use change was measured using QGIS[18] and Rstudio.[19]

FIGURE ES 1.6: URBAN HEAT EXPOSURE RISK ASSESSMENT FRAMEWORK, SEFORALL



[16] Global Land Cover, Copernicus. Land Cover Viewer (vito.be)

[17] Buchhorn, M. ; Lesiv, M. ; Tsendbazar, N. - E. ; Herold, M. ; Bertels, L. ; Smets, B. Copernicus Global Land Cover Layers — Collection 2. Remote Sensing 2020, 12, Volume 108, 1044. DOI 10.3390/rs12061044

[18] Q-GIS software was used, which is a free and open-source cross-platform GIS software application that supports viewing, editing, and analysis of geospatial data. Discover QGIS

[19] RStudio is an Integrated Development Environment (IDE) for R, a programming language for statistical computing and graphics. About RStudio - RStudio

CHAPTER THREE: TRACKING THE ENABLING ENVIRONMENT FOR SUSTAINABLE COOLING

We need to rapidly shift to sustainable technologies, so access to cooling does not worsen global climate change. The good news is, many solutions already exist today to reduce risk, improve lives, and reduce emissions. And if we achieve universal electrification and end poverty by 2030, we will relieve almost 450 million people from extreme risks to their health and safety due to a lack of access to cooling. We must all commit to urgent action.

DAMILOLA OGUNBIYI

CEO and Special Representative of the UN Secretary-General for SEforALL and Co-Chair of UN-Energy

Delivering enhanced access to sustainable cooling solutions depends on a broad variety of enabling factors. This chapter of *Chilling Prospects* focuses on three of these factors:

- Policy Progress
- Financial Flows
- Community of Practice

Policies on sustainable cooling have made important progress since the Kigali Amendment, including national commitments in Nationally Determined Contributions (NDCs) and National Cooling Action Plans (NCAPs), with increased focus turning to sectoral policies that are crucial to enhancing investment. The combination of affordable, active and passive technology, services, finance, and policy solutions constitute the basic solution pillars to create an enabling environment for sustainable cooling. For the first time, the Chilling Prospects series provides a deep dive on the policy progress for sustainable cooling, with an assessment of progress for the Critical 9 countries.[20]

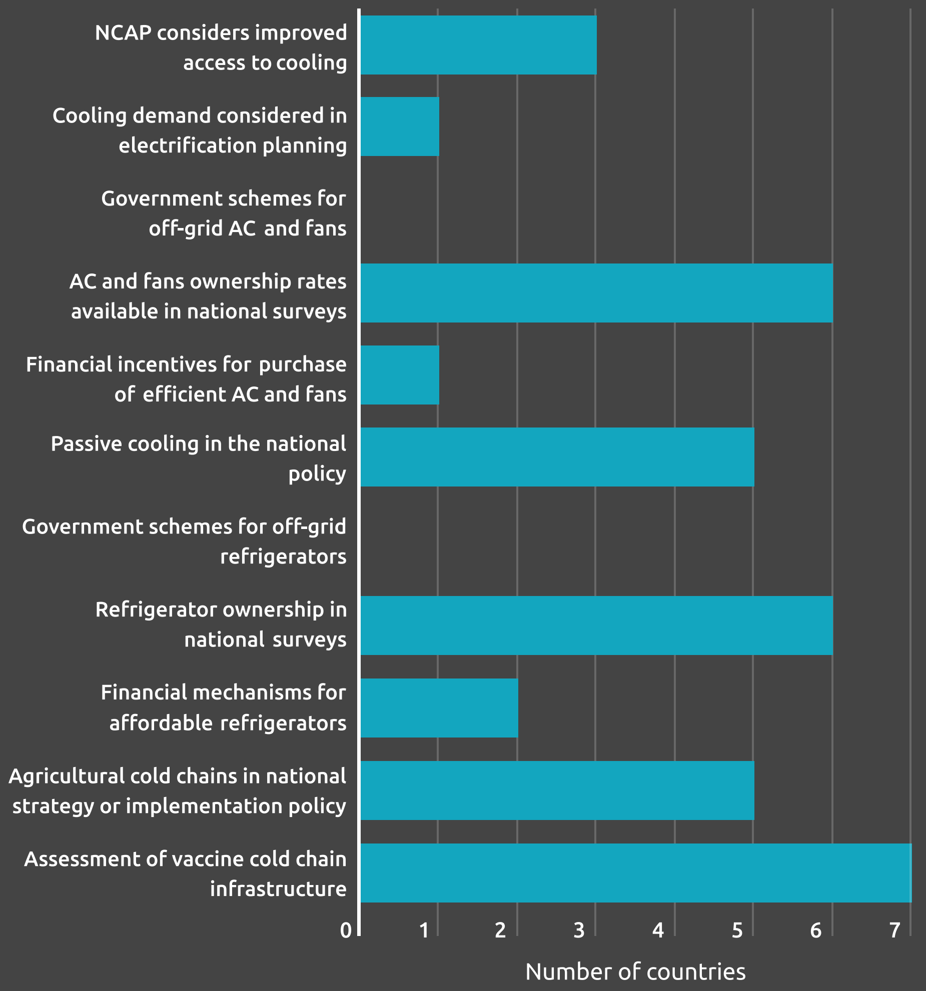
Policy tracking in Chilling Prospects 2022 includes assessing current policy for: **(i) access to cooling; (ii) energy efficiency for air conditioners, fans, refrigerators and buildings; and (iii) climate change policies for cooling** across the three Cooling for All needs (food, nutrition and agriculture; health services; and human comfort and safety) in the Critical 9 Countries. The analysis shows that regulatory, information and incentive policies covering key cooling solutions (air conditioners, fans, refrigerators, efficient buildings, and agricultural and vaccine cold chains) in Critical 9 countries have been improving, but progress remains uneven and policy efforts need to be sustained.

[20] The *Critical 9* refers to the top nine high-impact countries for access to cooling. They are: Bangladesh, Brazil, China, India, Indonesia, Mozambique, Nigeria, Pakistan and Sudan.

ES TABLE 1.2: COOLING FOR ALL POLICY TRACKING APPROACH

WHAT IS THE STATUS OF THE NCAP? (NOT PLANNED, UNDER DEVELOPMENT, PUBLISHED)		
ACCESS TO COOLING To what extent do policies enhance access to cooling?	**ENERGY EFFICIENCY FOR COOLING** To what extent do policies enhance efficiency of ACs, fans, refrigerators and buildings?	**CLIMATE MITIGATION FROM COOLING** To what extent is cooling reflected in climate targets?
• Does the NCAP consider improved access to cooling? • Is cooling demand considered in electrification planning? • Are there government programmes for off-grid refrigerators, ACs and/or fans? • Is the ownership rate of refrigerators, ACs and/or fans available? (through national surveys or other national initiatives?) • Are there financial incentives for the purchase of refrigerators, ACs and/or fans? • Is there an assessment of vaccine cold chain infrastructure? • Are agricultural cold chains recognized in a national strategy or implementation policy for sustainable cooling? • Is passive cooling recognized in the national building code or other national strategy or implementation policy for sustainable cooling?	• Are there energy services agreements (energy performance contracts)? • Have minimum energy performance standards been adopted for refrigerators, ACs and fans? • Is there a policy for regulating efficiency of imported refrigerators, ACs and/or fans? • Has energy-efficiency labelling been adopted for refrigerators, ACs and/or fans? • Is energy-efficiency labelling for refrigerators, ACs and/or fans mandatory? • Are there energy-efficiency codes for new residential and/or commercial buildings? • Are there energy-efficiency codes for existing residential and/or commercial buildings? • Are energy-efficiency codes mandatory? • Are there financial incentives for efficient cooling in buildings? • Are there non-financial incentives for efficient cooling in buildings?	• Is cooling considered in the NDCs? • Has the Kigali Amendment been ratified?

FIGURE ES 1.7: INDICATORS FOR PROGRESS ON ACCESS TO COOLING POLICIES IN THE CRITICAL 9 COUNTRIES



Similarly, finance has begun to flow, and while delivery of sustainable solutions will require leadership from the private sector, public finance, including climate finance is now working to address sustainable cooling in earnest. In 2021 however, there was a shift beyond projects focused on efficient space cooling, with a **significant amount of international climate finance mobilized for access to cooling**. In October 2021, the Green Climate Fund (GCF) approved a World Bank **Cooling Facility** with USD 157 million in direct GCF financing, which will be leveraging USD 722 million in World Bank co-financing. The facility will be administered by the World Bank and **support projects in nine countries across the health, agriculture and space cooling sectors**: Bangladesh, El Salvador, Kenya, Malawi, North Macedonia, Panama, Sao Tome and Principe, Somalia and Sri Lanka. The availability of technical assistance to improve investment environments has grown significantly, with important contributions from the World Bank ESMAP's Efficient Clean Cooling Program, Clean Cooling Collaborative NDC facility, and United for Efficiency. New initiatives and tools such as the Africa Center for Excellence for Sustainable Cooling and Cold Chain and the Cool Coalition's model methodology for National Cooling Action Plans are now supporting the implementation of the best available knowledge on policy, technology, and business models, among others.

Underpinning this is a growing community of practice that is displaying the benefits of collaboration and knowledge-sharing given limited resources and complex problems, with new partnerships, awareness raising, and information sharing among and outside this community remaining a key need. Coordination among partners remains critical, with the Cool Coalition working as a global, multi-stakeholder network to connect a range of actors to facilitate knowledge exchange and coordinate advocacy on cooling as both a climate change and development issue. SEforALL's Cooling for All programme supports this overall global mission, with a focus on providing the data, knowledge, and policy support necessary to deliver access to sustainable cooling in service of the SDGs.

FIGURE ES 1.8: ENERGY-EFFICIENT COOLING POLICIES IN THE CRITICAL 9 COUNTRIES

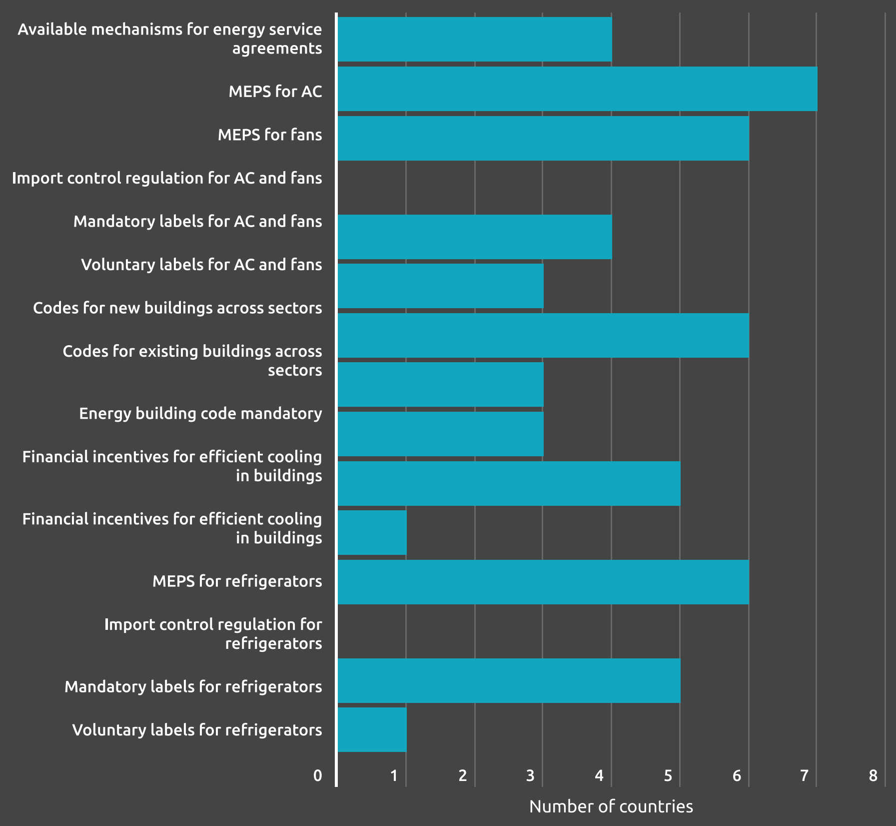
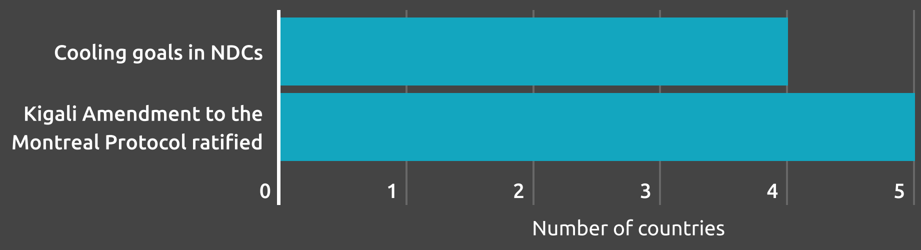


FIGURE ES 1.9: COOLING IN NATIONAL CLIMATE PLANNING IN THE CRITICAL 9 COUNTRIES



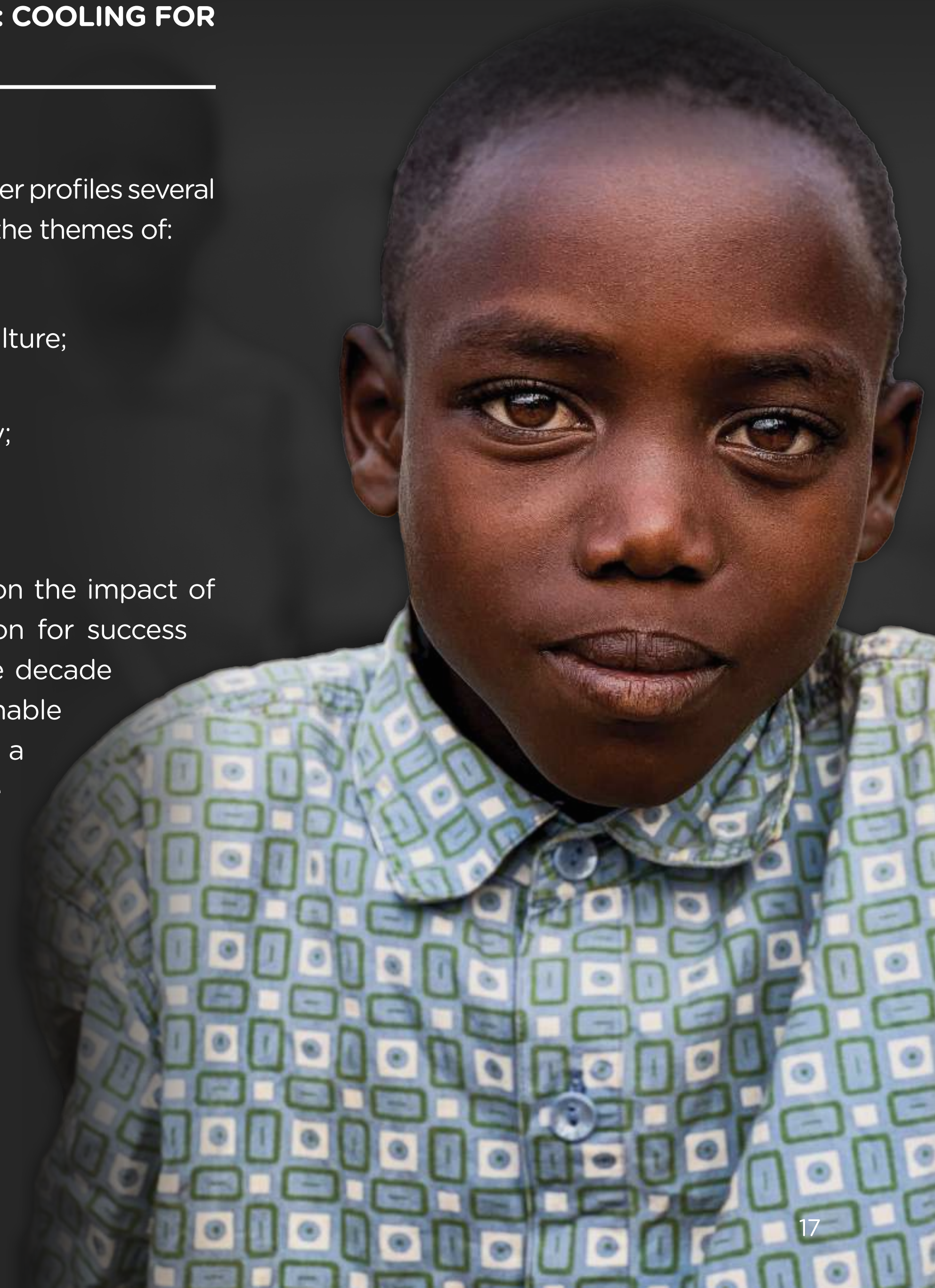
CHAPTER FOUR: REFLECTING ON FIVE YEARS OF THE KIGALI AMENDMENT: COOLING FOR ALL PARTNER STORIES

The Kigali Amendment to the Montreal Protocol was signed in late 2016, with countries committing to cut the production of hydrofluorocarbons, powerful greenhouse gases typically used as refrigerants, by more than 80 percent over the next 30 years. The Amendment offered a historic opportunity to link its implementation with the improvement of energy efficiency in active cooling technologies, and to use holistic strategies to deliver on the cooling needs of vulnerable populations while reducing the overall energy demand needed for cooling. Since 2016, a growing number of initiatives have put these words to action, in support of the Kigali Amendment, the Paris Agreement on Climate Change, and the Sustainable Development Goals.

This includes the Sustainable Energy for All Cooling for All program, begun in 2017 with support of the Kigali Cooling Efficiency Program (now Clean Cooling Collaborative). Since 2017, the Cooling for All programme has advocated for greater action on sustainable cooling and developed evidence, policy, and tools to make that action possible. This chapter profiles several interventions in action across the themes of:

- Global Voices;
- Food, Nutrition, and Agriculture;
- Health Services;
- Human Comfort and Safety;
- Finance; and
- Regional Perspectives.

Each story provides insight on the impact of their work, as well as a vision for success in 2025, halfway through the decade of action for the Sustainable Development Goals and a critical milestone for the Paris Agreement on Climate Change.



CHILLING PROSPECTS

CHAPTER ONE

Global Access to Cooling Gaps

1.1 Introduction

For millions of people, daily life carries on when temperatures hit heatwave levels. But those living below the poverty line or without access to reliable, affordable, and sustainable energy, their ability to adapt and thrive is held back without access to cooling.

The risks of extreme heat to human health and productivity are already apparent and increase as temperatures rise. A lack of access to cooling also threatens the essential products we rely on such as COVID-19 vaccines, medicines, and nutritious food – and the ability to get them to the last mile where they are needed most. Globally, failing to deliver on growing cooling needs without sustainable solutions will put the Sustainable Development Goals (SDGs) out of reach for too many.

Cooling is also a make-or-break issue for the planet. Cooling already consumes 17 percent of global electricity demand, and this figure could triple by 2050.[1] Without access to sustainable, affordable solutions and holistic planning to meet cooling needs, achieving SDG7 will be delayed, threatening the Paris Agreement and our ambition for a net-zero future.

Today, it is the poor who suffer the most from a lack of access to sustainable cooling. This includes farmers, who can't grow and sell perishable crops due to lack of access to cold chains that connect them to more lucrative markets. It also includes women, who are at high risk of heat stress in their jobs and during pregnancy; youth, whose opportunity and productivity are being diminished in the absence of comfortable learning environments; and children who may suffer the consequences of ineffective vaccines.[2] According to new research from The Lancet, in 2019 over 350,000 people across the world lost their lives due to extreme heat.[3]

Chilling Prospects 2022 shows us that the risks to people, products and the planet are growing, with the risk from a lack of access to cooling rising again compared to last year. This chapter summarizes global access to cooling risks, assesses populations at risk in high-impact countries and non-high-impact countries, and provides a forecast for access to cooling in 2030 using SDG-based scenarios. The data in this report make it clear: equitable economies, access to sustainable energy, and just, inclusive clean energy transitions are only possible with sustainable cooling for all.

[1] IEA, Future of Cooling, 2018.

[2] SEforALL (2021). Cooling For All and Gender. Link.

[3] Burkart, et al, Health in a World of Extreme Heat, The Lancet Vol 398, August 2021. Link.

1.2 Global Access to Cooling Gaps[4]

This section examines global cooling-access gaps among 54 high-impact countries and the high-temperature regions of 22 countries not considered high impact. It disaggregates between populations at high risk due to a lack of access to cooling (the rural and urban poor), those at medium risk (the lower-middle-income population) and those at low risk (the middle-income population). While most of the populations at high risk are in high-impact countries, efforts to leave no one behind must recognize where risk exists, even in countries not considered high impact. Sections 1.3 and 1.4 disaggregate the data for risk groups between these two country types.

HIGH RISK

In 2022, across 54 high-impact countries[5] and high-temperature regions of 22 countries not considered high impact, 1.2 billion rural and urban poor are at high risk because they lack access to cooling. Of this figure, 1.17 billion live in high-impact countries. This represents **an increase of more than 28 million people** since 2021. The number of urban poor at high risk increased by 24.9 million people in high-impact countries, driven by a strong urbanization trend, while there was a reduction in urban poor at risk of 94,000 people in non-high-impact countries. The rural poor at high risk grew by nearly 4 million from 372.7 million to 376.6 million, with most of the increase in high-impact countries. This increase was driven by several factors, most notably the economic impact of the COVID-19 pandemic that continued to affect the rural poor, with urbanization offsetting potentially higher growth.

[4] Each year, the Chilling Prospects report projects an estimate of the current state of access to cooling gaps, based on the best available data and evidence. Chilling Prospects 2022 presents an analysis of cooling access gaps at the beginning of 2022, based on the best available data, primarily 2021 statistics and information.

[5] High-impact countries are those expected to experience sustained high temperatures which also have significant populations at high risk from a lack of access to cooling due to poverty and electricity access gaps. For a full list, see here.

FIGURE 1.1: POPULATION BY COUNTRY AT HIGH RISK DUE TO A LACK OF ACCESS TO COOLING

In the Critical 9 countries,[6] the number of people at high risk (rural and urban poor) grew by an average of 7 percent over the last year, with an increase in all countries except for Indonesia. India and China have the largest populations at high risk in absolute numbers (almost 323 million and 159 million, respectively), while Mozambique and Nigeria have the largest relative share of rural and urban poor among the Critical 9 countries, with 84 percent and 67 percent of the total population at high risk respectively.

In the 2022 analysis, the rural poor and urban poor risk groups grew at a faster rate than in previous years. Several factors contributed to this trend, including gaps in access to modern, reliable energy services

[6] The Critical 9 countries are: Bangladesh, Brazil, China, India, Indonesia, Mozambique, Nigeria, Pakistan and Sudan.

and the ongoing effects of the COVID-19 pandemic on global extreme poverty.[7] The countries with the most significant proportion of their populations at high risk remain in Africa, and include Guinea-Bissau and Somalia, where over 90 percent of the total population is at high risk, as well as Angola, Benin, Liberia and Mozambique, where over 80 percent is at high risk.

MEDIUM & LOW RISK

The lower-middle-income population at medium risk increased from 2.36 billion to 2.47 billion compared to last year, including an increase of 108.8 million among high-impact countries and a decrease of 5 million among non-high-impact countries. Income loss during the pandemic, in combination with other factors, brought the lower-middle-income population back to similar levels as in 2018, when the access to cooling tracking efforts began. Among this group, it is estimated that in 2021 an additional 165 million people globally lived on less that USD 5.50 per day because of the pandemic, 119 million of them in East and South Asia and the Pacific, 29 million in Africa and the Middle East, and 12 million in Latin America and the Caribbean.[8]

At the same time, the middle-income population decreased by 76.7 million, from 1.44 billion to 1.36 billion in the 2022 analysis, a figure that includes a 75.7 million person decrease among the high-impact countries.

ACCESS TO COOLING RISKS

Across the 54 high-impact countries and 22 non-high-impact countries, at least 3.66 billion people face high or medium risk from some type of cooling access challenge, an increase of 132 million people compared to last year. A further 1.36 billion people are at low risk, but serious risks are still posed by this population to climate and energy systems, where people choose ownership of cooling appliances that are not sustainable.

[7] World Bank (2021) *COVID-19 leaves a legacy of rising poverty and widening inequality.* Link.

[8] World Bank (2021) *Poverty, median incomes, and inequality in 2021: a diverging recovery.* Link.

TABLE 1.1: ANALYSIS OF RISK FROM A LACK OF ACCESS TO COOLING

GLOBAL ACCESS TO COOLING POPULATION AT RISK (for 54 high-impact countries and 22 countries not considered high impact)				
RISK SPECTRUM	**HIGH RISK**		**MEDIUM RISK**	**LOW RISK**
	• No access to electricity • Income below poverty line • Poor ventilation and construction • No access to refrigeration for food • Farmers lack access to cold chains • Vaccines exposed to high temperatures		• Access to electricity • Lower income levels • Ability to run a fan, buildings constructed to older standards • Food is refrigerated • Farmers only have access to intermittently reliable cold chains • Vaccines may have exposure to occasional high temperatures	• Full and reliable electricity • Middle income and higher • Well-built homes can include insulation, passive design, air conditioning • Food is refrigerated reliably • Farmers' goods and vaccines have well-controlled cold chains
RISK POPULATIONS	**RURAL POOR**	**URBAN POOR**	**LOWER-MIDDLE INCOME**	**MIDDLE INCOME**
RISK INDICATORS	• Lack of access to energy • Population living in rural areas on less than $1.90/day[10]	• Lack of access to energy • Population living in urban slums on less than $1.90/day	• Population living on less than $10.01/day outside of rural or urban poverty	• Population living on between $10.01 and $20/day
2022 ACCESS GAP	**376.6 MILLION**	**821.5 MILLION**	**2.47 BILLION**	**1.36 BILLION**
2021 ACCESS GAP	**372.7 MILLION**	**796.7 MILLION**	**2.37 BILLION**	**1.44 BILLION**
CHANGE	**+3.9 MILLION**	**+24.8 MILLION**	**+103.8 MILLION**	**-76.7 MILLION**
FINDINGS & TRENDS	Despite steady electricity access improvements, risk-mitigating effects are outweighed by an increase in rural population that may not have access to, or be able to afford, adequate energy services for cooling	Urbanization, coupled with marginal electricity access, COVID-19 induced urban poverty, and effects of urban heat islands produce a consistently increasing risk	Pandemic-associated income loss, together with a dramatic increase of 165 million people globally living on less than $5.50/day contributed significantly to the increase	Increase in the number of people living on less than $20/day offset by a sharper increase in rural and urban poor as well as in lower-middle-income populations.
NOTES	• 1.2 billion people among the rural and urban poor are at high risk because they lack access to cooling. This includes 1.17 billion people in high-impact countries and 30.7 million people in non-high-impact countries. • The rural and urban poor increased by 28.6 million people in the 2022 analysis. This includes an increase of 28.8 million in high impact countries and a decrease in non-high impact countries. • The increase in those at high risk is driven by a 24.8 million increase among the urban poor			

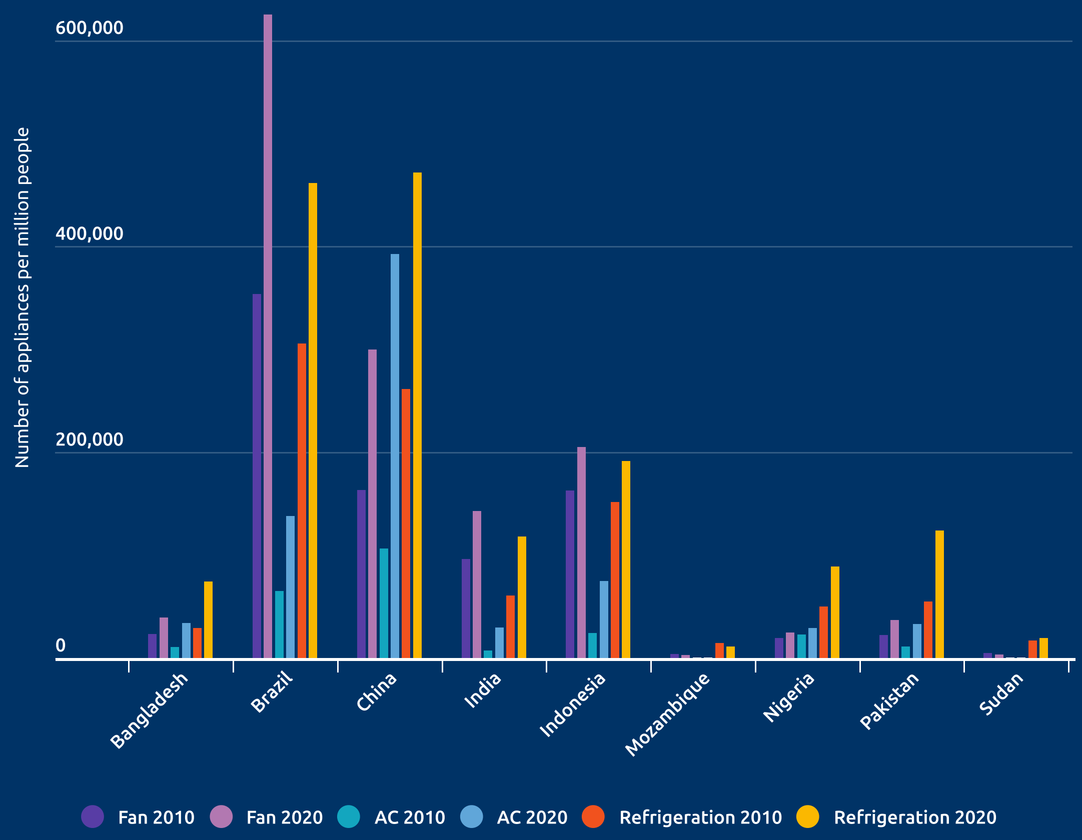
*Note: figures may not sum due to rounding.

[10] Dollar figures in this report refer to United States Dollars

While higher temperatures and living standards drive demand for cooling, and access to electricity access is a key enabler for cooling services, the ability of households to own and operate appliances largely corresponds to trends in income and urbanization.[11] For example, in India, which has a population of 1.4 billion, despite electricity access having approached 100 percent, cooling appliance ownership remains low, with an estimated ownership of 196 million fans, 162 million refrigerators and 40 million air conditioners.

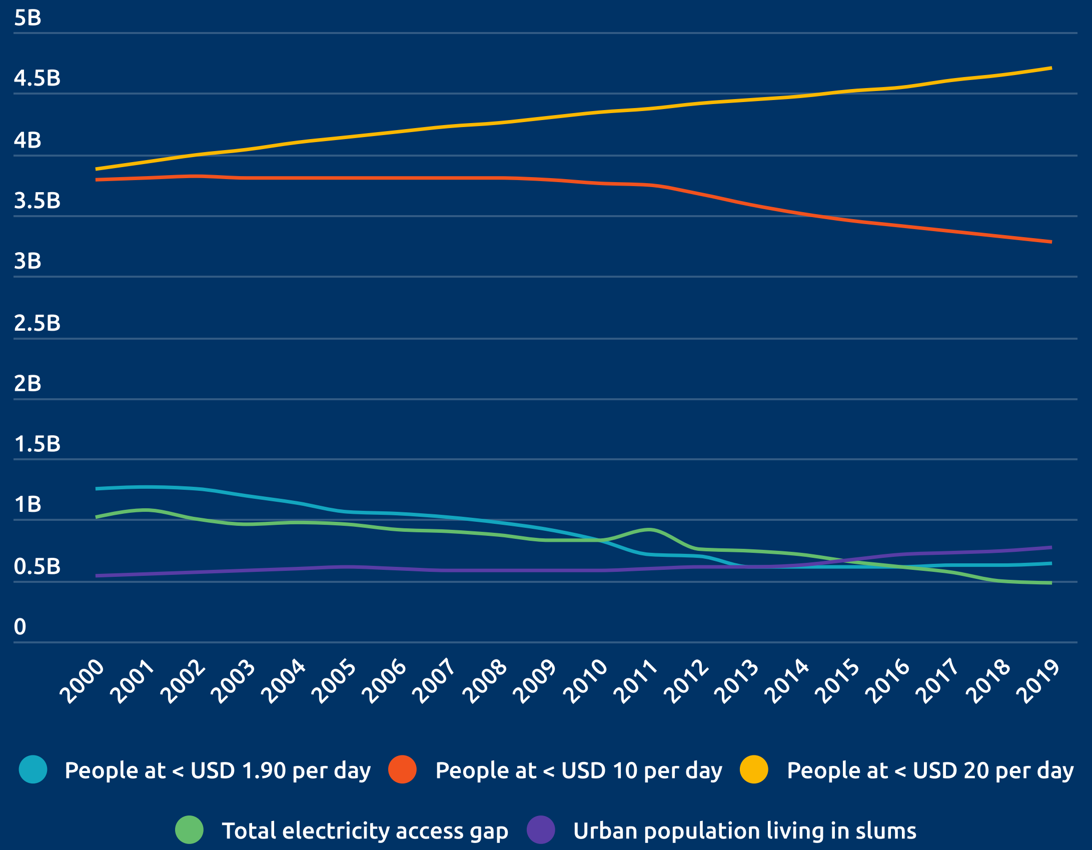
Assessing 20-year historical trends in poverty, electricity access, population and urbanization finds that while progress on electricity access has continued steadily, the global population has increased across all risk groups. This increase has been driven by a variety of factors including trends in population and income growth, urbanization and extreme poverty.

FIGURE 1.2: COOLING APPLIANCE OWNERSHIP AND ELECTRICITY ACCESS IN THE CRITICAL 9 COUNTRIES



[11] Poblete-Cazenave et al. (2021). Global scenarios of household access to modern energy services under climate mitigation policy. Link.

FIGURE 1.3: KEY ACCESS TO COOLING RISK INDICATORS (2000–2019)



1.3 Populations at Risk in the 54 High-impact Countries for Access to Cooling

Among the 54 high-impact countries, the number of urban poor at high risk increased by 24.8 million compared to last year, up to 796.5 million people. The rural poor population also grew by 3.9 million, from 366.9 million last year to 370.8 million in the 2022 analysis. While electricity access gaps continued to decline in both rural and urban areas, the number of people living in extreme poverty in the 54 high-impact countries increased by an additional 16 million. In high-impact countries, the lower-middle-income population continued its growth in the 2022 analysis, increasing by 108.8 million, to 2.39 billion people. Conversely, the middle-income population declined substantially, by approximately 75.7 million from 1.38 billion in 2021 to 1.3 billion in the 2022 analysis.

1.3.1 Rural poor at risk in 2022

Approximately 370.8 million people living in rural areas in high-impact countries lack access to electricity and are likely to live in extreme poverty. Many of the rural poor are likely to engage in subsistence farming but lack access to an intact cold chain that would enable them to sell their products further afield at a higher price. There may also be a lack of medical cold chains in rural poor communities, putting lives at risk from spoiled medicines and vaccines.

The number of rural poor at high risk in high-impact countries rose from approximately 366.9 million in 2021 to

371 million people in the 2022 analysis, an increase of approximately 4 million people. This increase was driven by several factors, most notably the economic impact of the COVID-19 pandemic that continued to affect the rural poor, with urbanization offsetting potentially higher growth.

In 2022, the estimated rural population living on less than USD 1.90 a day in the 54 high-impact countries had increased by 10 percent compared to pre-pandemic levels, and by more than 2 percent since 2020. Updated estimates by the World Bank suggest that the COVID-19 pandemic forced an additional 97 million people into extreme poverty, bringing the global figure up to 711 million. Of these, 478 million live in Sub-Saharan Africa and over 140 million live in South Asia. So, despite steady improvements in rural electricity access in high-impact countries, the risk-mitigating effects were outweighed by an increase in the rural population that may not have access to, or be able to afford, adequate energy services for cooling.

FIGURE 1.4: RURAL POOR POPULATION BY COUNTRY AT HIGH RISK DUE TO A LACK OF ACCESS TO COOLING

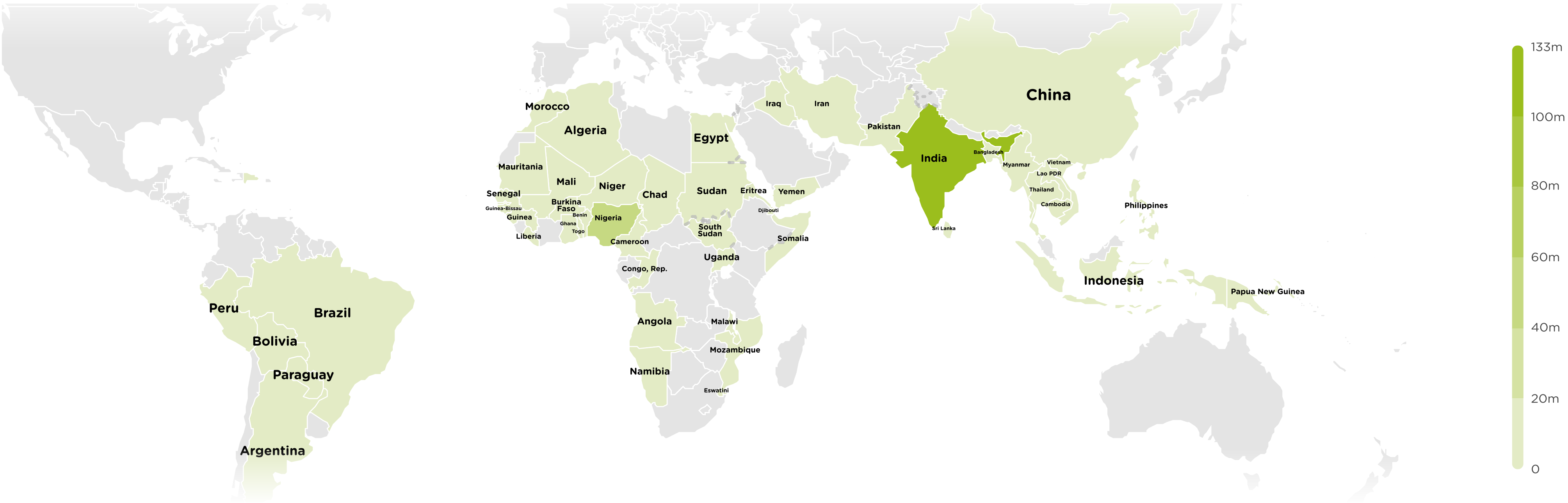
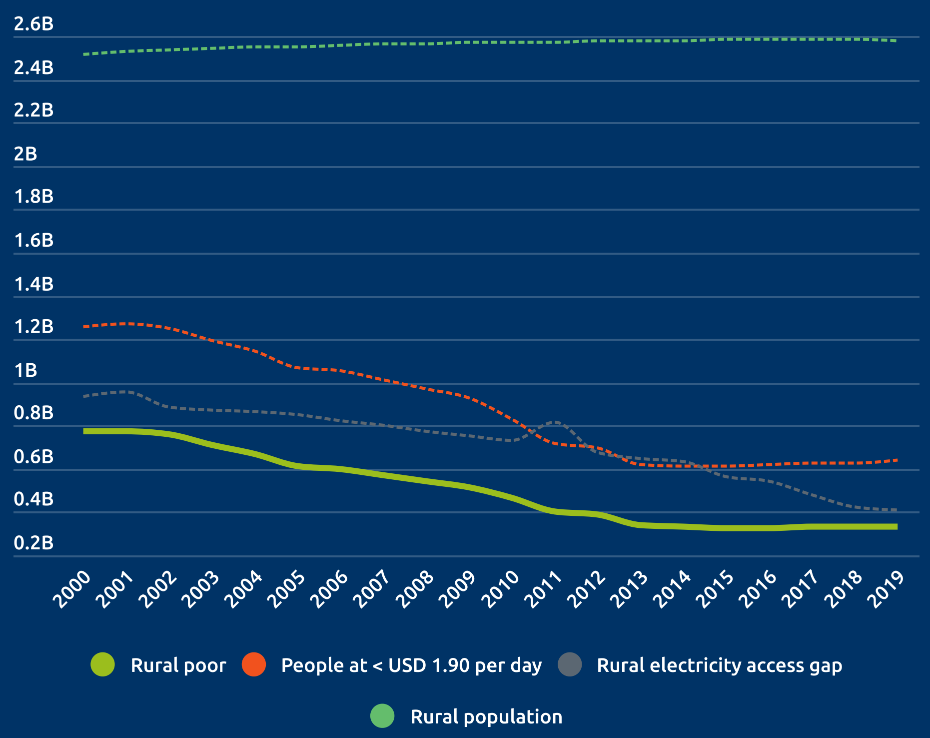


FIGURE 1.5: ACCESS TO COOLING RISK TRENDS FOR THE RURAL POOR (2000–2019)



The three countries with the highest number of rural poor at risk remain India, Nigeria and Bangladesh. India saw an increase in its rural poor population of 5.2 million people, while Nigeria and Bangladesh saw relatively small increases. The greatest proportional increases over the last year were seen in Egypt and Sri Lanka, rising 4.6 percent in each country respectively. Since the beginning of the tracking effort in 2018, Argentina (82 percent), Pakistan (21.8 percent), and Iraq (20.9 percent) have seen the largest proportional increases in their rural poor populations, while the most significant reductions occurred in Bolivia (-46.5 percent) and Indonesia (-42.3 percent).

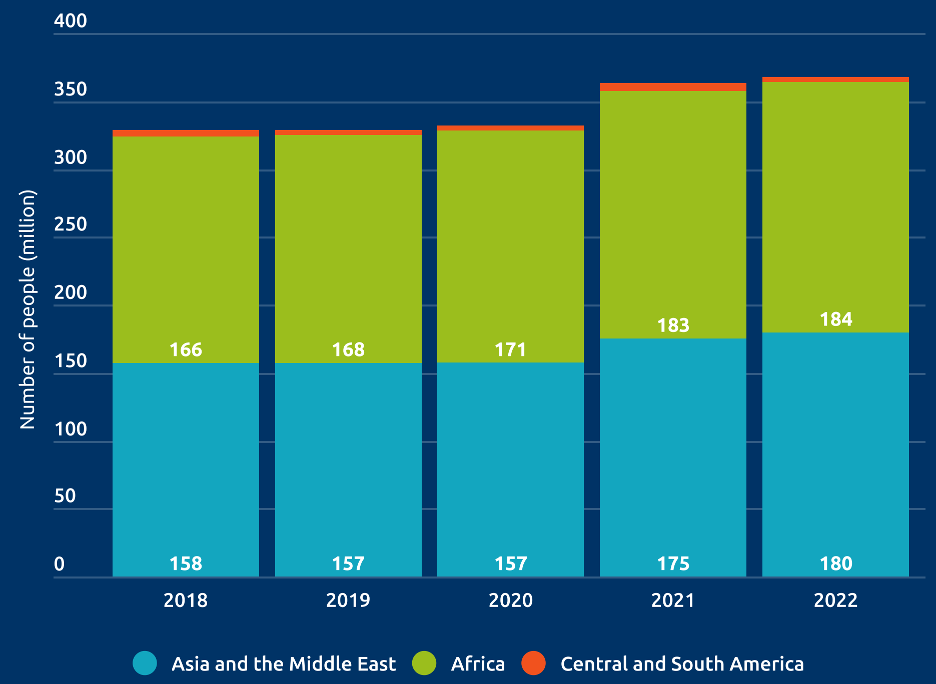
TABLE 1.2: TOP 10 COUNTRIES WITH RURAL POOR AT RISK (2020–2022)

	2020	2021	2022
India	113,978,712	128,033,279	133,323,222
Nigeria	48,428,631	51,669,454	51,499,589
Bangladesh	16,720,714	18,638,730	19,263,831
Uganda	14,942,836	16,012,123	16,046,934
Mozambique	14,043,915	15,045,874	15,079,742
Malawi	11,230,657	12,073,797	12,153,095
Niger	9,272,063	9,980,599	10,061,142
Angola	7,998,734	8,534,853	8,534,853
Somalia	6,960,362	7,447,457	7,454,750
Burkina Faso	6,899,429	7,388,497	7,388,497

Regional Analysis

Regionally, high-impact countries for access to cooling in Africa continue to be home to the greatest number of the rural poor in absolute terms, following a small increase in their number since 2020 when the economic shockwaves of the COVID-19 pandemic began to be felt.

FIGURE 1.6: RURAL POOR REGIONAL BREAKDOWN (2018–2022)

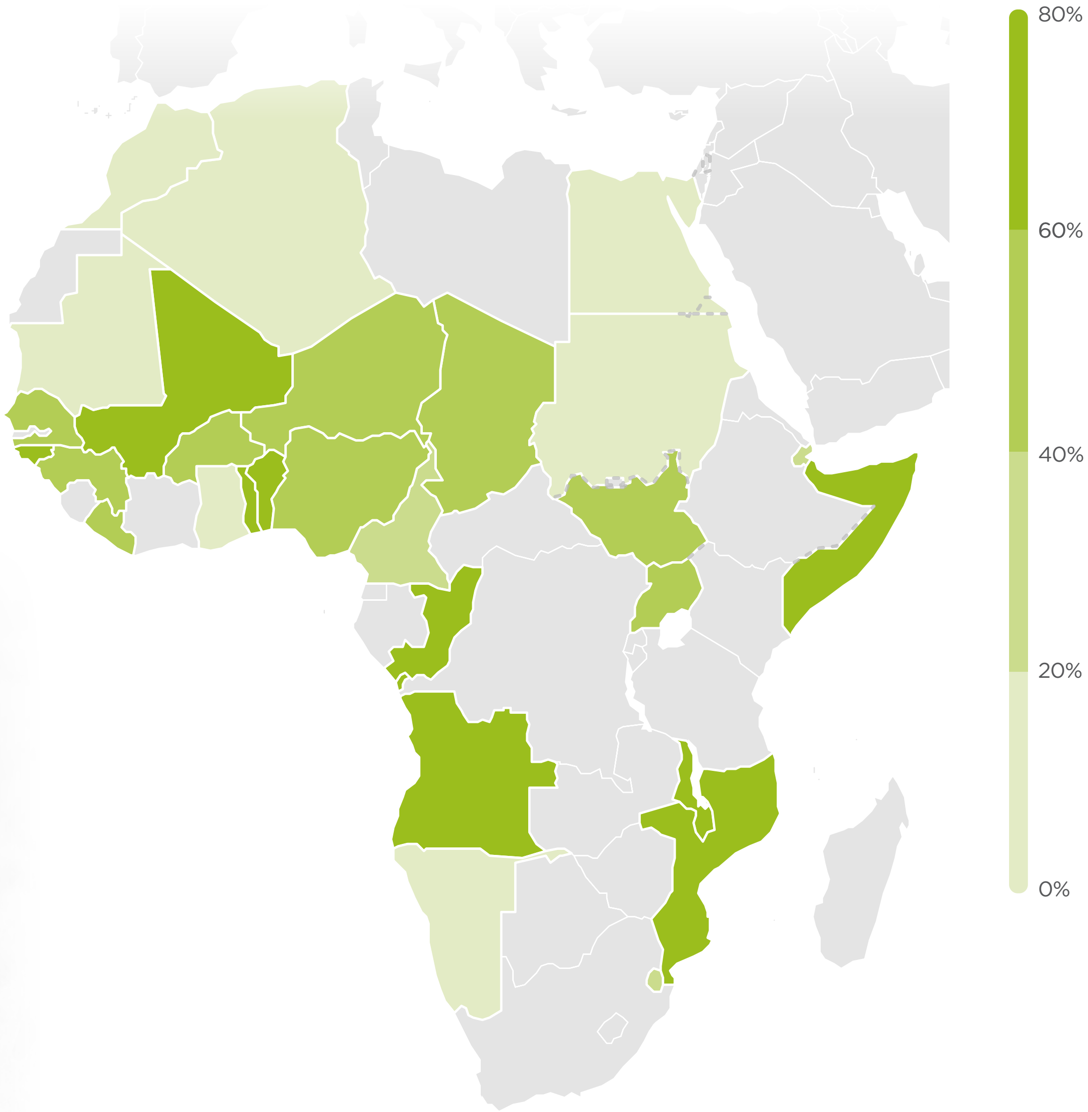


In 31 African high-impact countries, the number of rural poor grew marginally in the 2022 analysis compared to 2021, with an increase of 400,000 people. Half of the global rural poor population continues to live in Africa, representing 40 percent of all rural dwellers in these countries and 5 percent of the total rural population globally. Of the top 10 countries with the highest number of rural poor at risk, eight are in Africa. More concerning is that more than half of the rural populations in a significant number of countries in Africa are at high risk due to lack of access to cooling, including Angola, Guinea-Bissau, Malawi, Mozambique and Somalia, where more than three-quarters of all rural dwellers are at high risk.

In 16 high-impact countries in Asia and the Middle East, the number of rural poor at risk has increased by 4.3 million people over the last year. Yemen (24 percent) and Timor-Leste (23 percent), have the highest proportion of rural poor at risk, while in absolute terms, India is home to 133.3 million rural poor, representing almost three-quarters of the rural poor in the region and 36 percent of the global rural poor population.

Latin America and the Caribbean are home to six high-impact countries for access to cooling which, combined, have 4.4 million people among the rural poor, or 1 percent of the total global population. In the 2022 analysis, the rural poor population declined in all six countries, by 6 percent on average. Brazil accounts for 3.6 million, or 82 percent of the rural poor in the region. The second largest rural poor population is in Peru, with 316,000 or 7.2 percent of the rural poor in the region.

FIGURE 1.7: SHARE OF RURAL POOR AS A PROPORTION OF THE RURAL POPULATION IN AFRICAN HIGH-IMPACT COUNTRIES (2022)



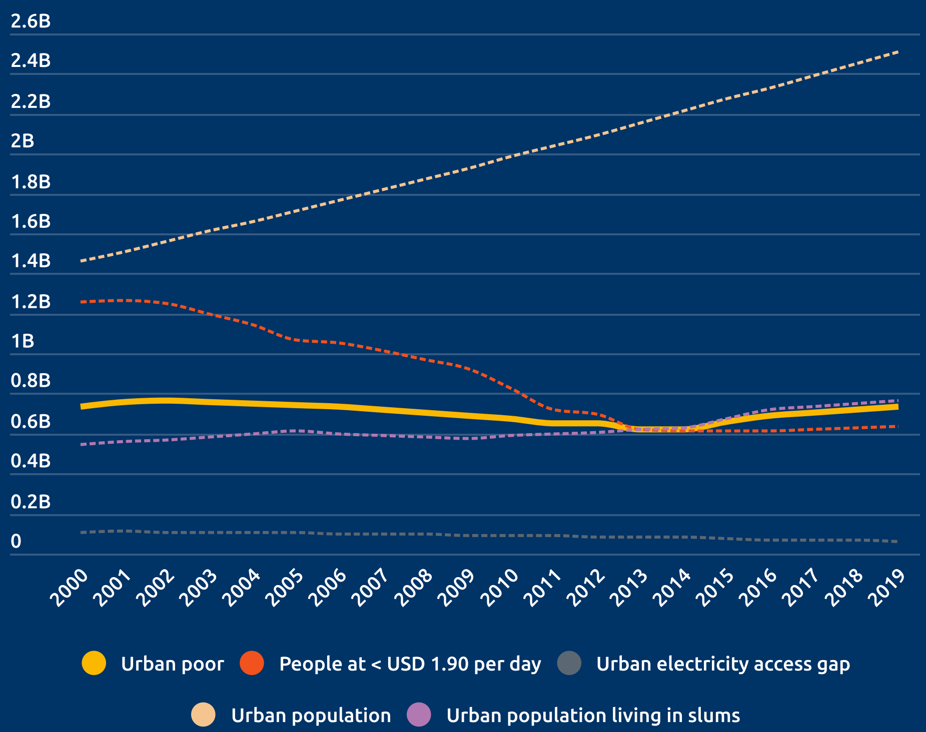
1.3.2 Urban poor at risk in 2022

FIGURE 1.8: URBAN POOR POPULATION BY COUNTRY AT HIGH RISK DUE TO A LACK OF ACCESS TO COOLING

Approximately 796.5 million people living in poor urban settings in high-impact countries are at high risk because they lack access to cooling. These people may have some access to electricity, but the quality of their housing is likely too poor to protect them from extreme heat, and their income may not be sufficient to purchase or run a fan. They may own or have access to a refrigerator, but intermittent electricity supplies may mean that food often spoils and there is a high risk of poor nutrition or food poisoning.

In high-impact countries, the number of urban poor at high risk rose significantly in the 2022 analysis, by approximately 24.8 million people from 771.6 million in 2021 to 796.5 million today. Since the beginning of the tracking effort in 2018, the number of urban poor at risk has increased dramatically, by 93.2 million people. This is due to a number of factors, including fast-growing urbanization across the 54 high-impact countries and associated challenges. This includes electricity access, which has risen consistently in the urban areas of high-impact countries during the last two decades but can often be marginal or unreliable during a heat wave. Poor urban dwellers also face specific risks related to increased heat exposure and challenges in accessing quality housing, green spaces and public cooling resources, particularly the growing number living in slums or informal settlements within the high-impact countries. Risks are exacerbated for the portion of the urban population that lives in extreme poverty, and in 2020–2021 the COVID-19 pandemic halted an otherwise declining trend in the number of people living on less than USD 1.90 a day in the 54 high-impact countries.

FIGURE 1.9: ACCESS TO COOLING: RISK TRENDS FOR THE URBAN POOR (2000–2019)



India, China and Nigeria remain the top three countries in absolute numbers for the urban poor. Together, they accounted for an increase of over 16 million in the urban poor population with India experiencing the most significant increase of 10.5 million people, or 6 percent compared to last year. The highest relative proportional increase of urban poor populations between 2021 and 2022 were seen in Yemen (10 percent) and Myanmar (7 percent). Significant decreases in urban poor populations were observed in Papa New Guinea (-11 percent), while Lao PDR and Timor-Leste saw the second biggest decrease at -3.9 percent each. Among the top 10 countries by absolute numbers, only Brazil and the Philippines saw the number of urban poor at high risk decline compared to 2021.

TABLE 1.3: TOP 10 COUNTRIES WITH URBAN POOR AT RISK (2020–2022)

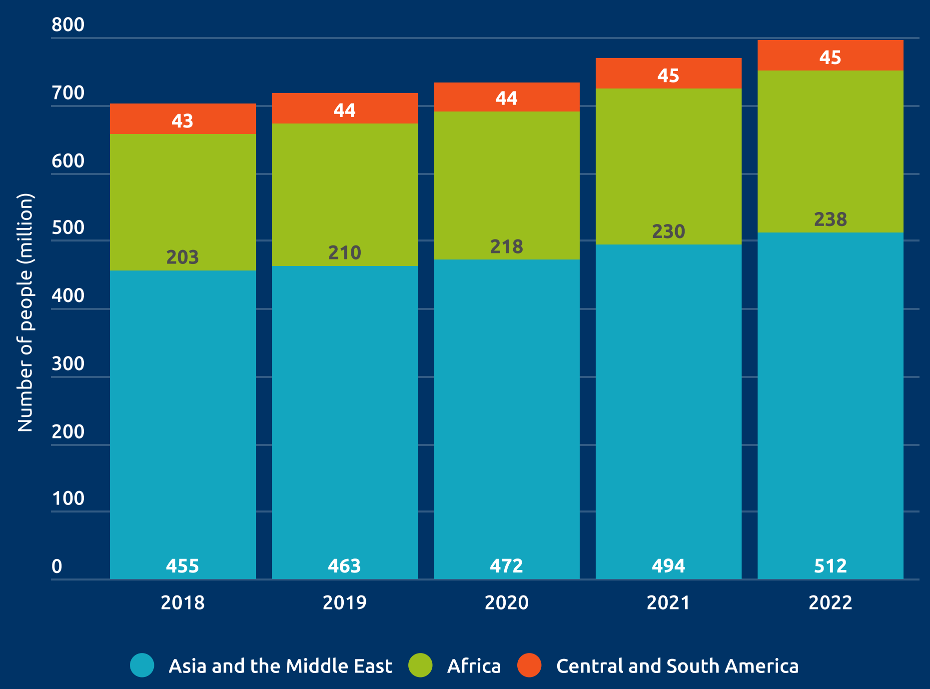
	2020	2021	2022
India	165,891,102	179,030,665	189,576,535
China	150,156,770	152,355,085	154,663,318
Nigeria	81,110,401	86,590,576	90,080,199
Indonesia	36,321,426	38,712,858	40,274,827
Bangladesh	28,692,549	30,090,527	30,783,901
Brazil	28,775,044	29,551,185	28,731,845
Pakistan	25,429,885	26,113,013	26,653,527
Angola	18,725,397	19,750,706	20,192,843
Philippines	18,542,873	19,198,292	19,194,992
Sudan	11,816,970	12,354,477	12,804,480

Regional Analysis

High-impact countries for access to cooling in Asia and the Middle East account for the majority of urban poor at high risk, and consistent growth in Africa has also been observed. For the first time since the beginning of the tracking effort, the number of urban poor at risk in Latin America and the Caribbean decreased.

Among African high-impact countries, the number of urban poor at risk grew by 7.8 million people, from 230.5 million last year to 238.3 million in 2022, representing 30 percent of the at-risk urban poor population globally. Nigeria accounted for 45 percent of the increase among African countries, with 3.5 million additional people among the urban poor. In addition to Nigeria, Angola, Cote d'Ivoire, Mozambique and Sudan all have urban poor populations above 10 million, while Chad, Malawi, Mozambique and Somalia all saw 5 percent increases in 2022 compared to 2021.

FIGURE 1.10: URBAN POOR REGIONAL BREAKDOWN (2018–2022)



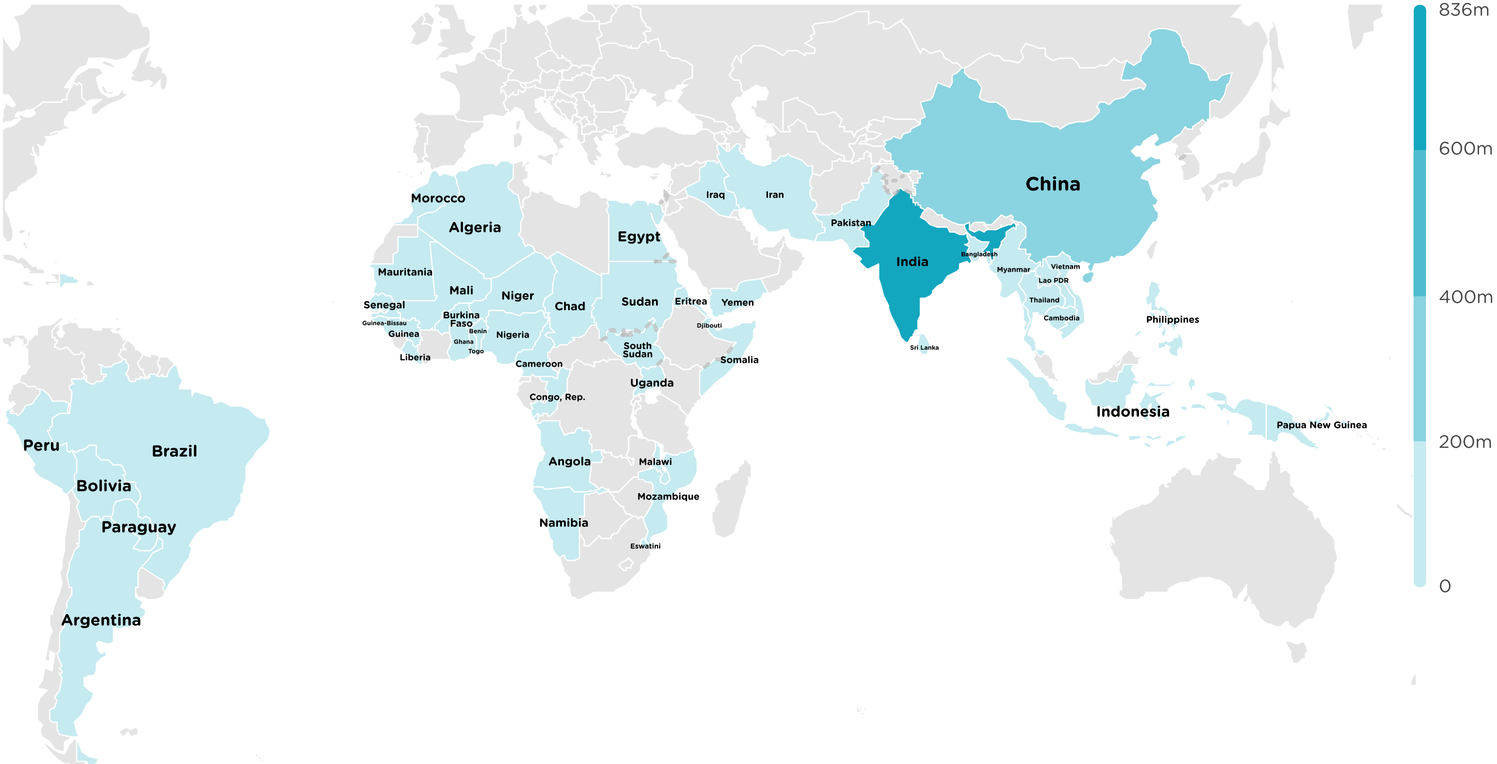
In 16 high-impact countries in Asia and the Middle East, 512.3 million urban dwellers are at high risk due to a lack of access to cooling, representing 64 percent of the urban poor population globally. As a proportion of the total urban population of these countries, just over a quarter, or 26 percent, are at high risk. Among this group, nine countries have urban poor populations that represent over 30 percent of all urban residents, led by Yemen where 74 percent of all urban residents are at high risk.

FIGURE 1.11: SHARE OF URBAN POOR AS A PROPORTION OF URBAN DWELLERS IN ASIA AND THE MIDDLE EAST (2022)

In the six Latin America and Caribbean countries considered high impact for access to cooling there was a reduction in the number of urban poor of over 420,000. This was driven by Brazil, which saw a reduction in its urban poor population of approximately 800,000 people, offset by marginal increases in Bolivia, the Dominican Republic, Paraguay and Peru.

1.3.3 Lower-middle-Income population at risk in 2022

FIGURE 1.12: LOWER-MIDDLE-INCOME POPULATION BY COUNTRY AT MEDIUM RISK DUE TO A LACK OF ACCESS TO COOLING



Approximately 2.39 billion people in high-impact countries represent an increasingly affluent lower-middle class that is on the brink of purchasing the most affordable air conditioner or refrigerator on the market. Limited purchasing choices available to this group favour cooling devices that are likely inefficient and could cause a dramatic increase in energy consumption and associated greenhouse gas (GHG) emissions.

The lower-middle income is the estimated segment of the population that lives outside of rural and urban poverty, though on less than USD 10.01 per day. In high-impact countries, the lower-middle income population continued its growth, increasing by 108.8 million people compared to last year, after an increase of 72.7 million people in 2020. Prior to the onset of the COVID-19 pandemic, a downward trend in the lower-middle-income population had been observed, matching the decline in the number of people living on low income. However, income loss during the pandemic, in combination with other factors, brought the lower-middle-income population back to similar levels as in 2018, when the tracking effort began. Among this group, it is estimated that an additional 165 million people globally lived on less that USD 5.50 per day due to the effects of the pandemic in 2021; of this number 82 million live in South Asia and 15 million in Sub-Saharan Africa.

India, China and Indonesia represented the top three countries by absolute numbers, with India increasing its lower-middle-income population by approximately 45.2 million people, compared to 23 million and 3.8 million in China and Indonesia respectively. The largest relative increases in the lower-middle-income population compared to 2021 were observed in Papua New Guinea (19.2 percent), Iran (13.4 percent), and Sudan (9.6 percent). Compared to last year, Mozambique saw the largest reduction in its lower-middle-income population, of approximately 18.2 percent, reflecting an increase in the urban poor (and, to a lesser extent, the rural poor) population that offset a 1.5 percent increase in the lower-middle-income segment.

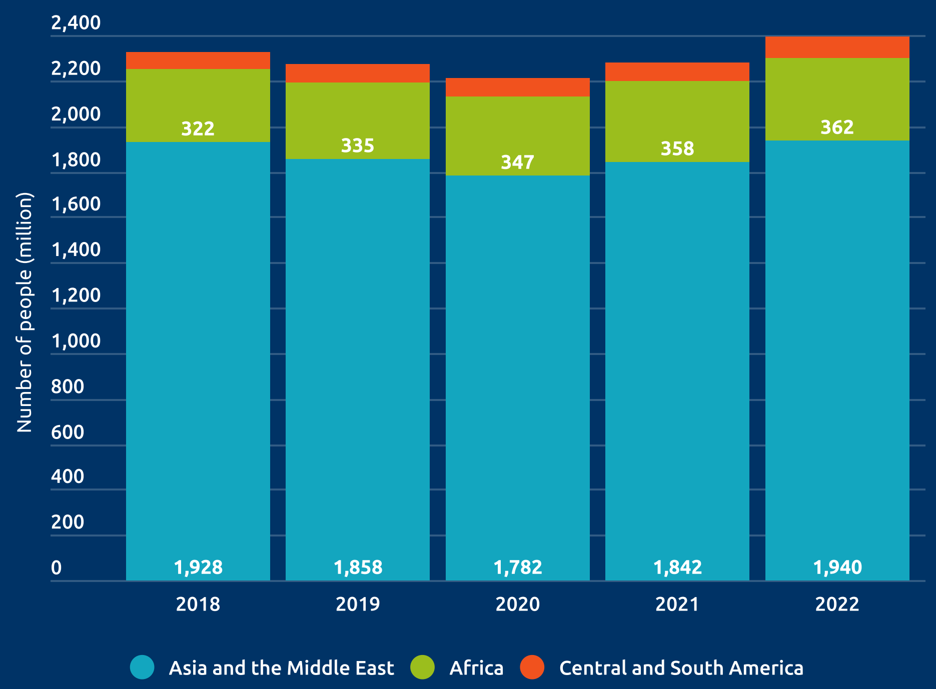
TABLE 1.4: TOP 10 COUNTRIES WITH LOWER-MIDDLE INCOME POPULATION AT RISK (2020–2022)

	2020	2021	2022
India	758,399,313	790,490,803	835,689,776
China	352,682,825	365,954,601	388,922,316
Indonesia	171,974,946	172,225,545	176,050,378
Pakistan	158,016,650	165,943,912	174,768,616
Bangladesh	108,150,572	111,908,918	117,873,505
Egypt	86,187,359	85,790,565	85,666,629
Nigeria	76,410,428	78,935,565	78,338,843
Philippines	56,081,318	56,229,901	58,731,568
Brazil	51,570,397	52,716,807	57,710,745
Vietnam	50,822,888	51,818,286	53,844,206

[12] World Bank (2021) *Poverty, median incomes, and inequality in 2021: a diverging recovery.* Link.

Regionally, high-impact countries in Asia and the Middle East continue to be home to the majority of the lower-middle-income population among the high-impact countries for access to cooling, with consistent growth across high-impact countries in each region.

FIGURE 1.13: LOWER-MIDDLE-INCOME POPULATION REGIONAL BREAKDOWN (2018–2022)



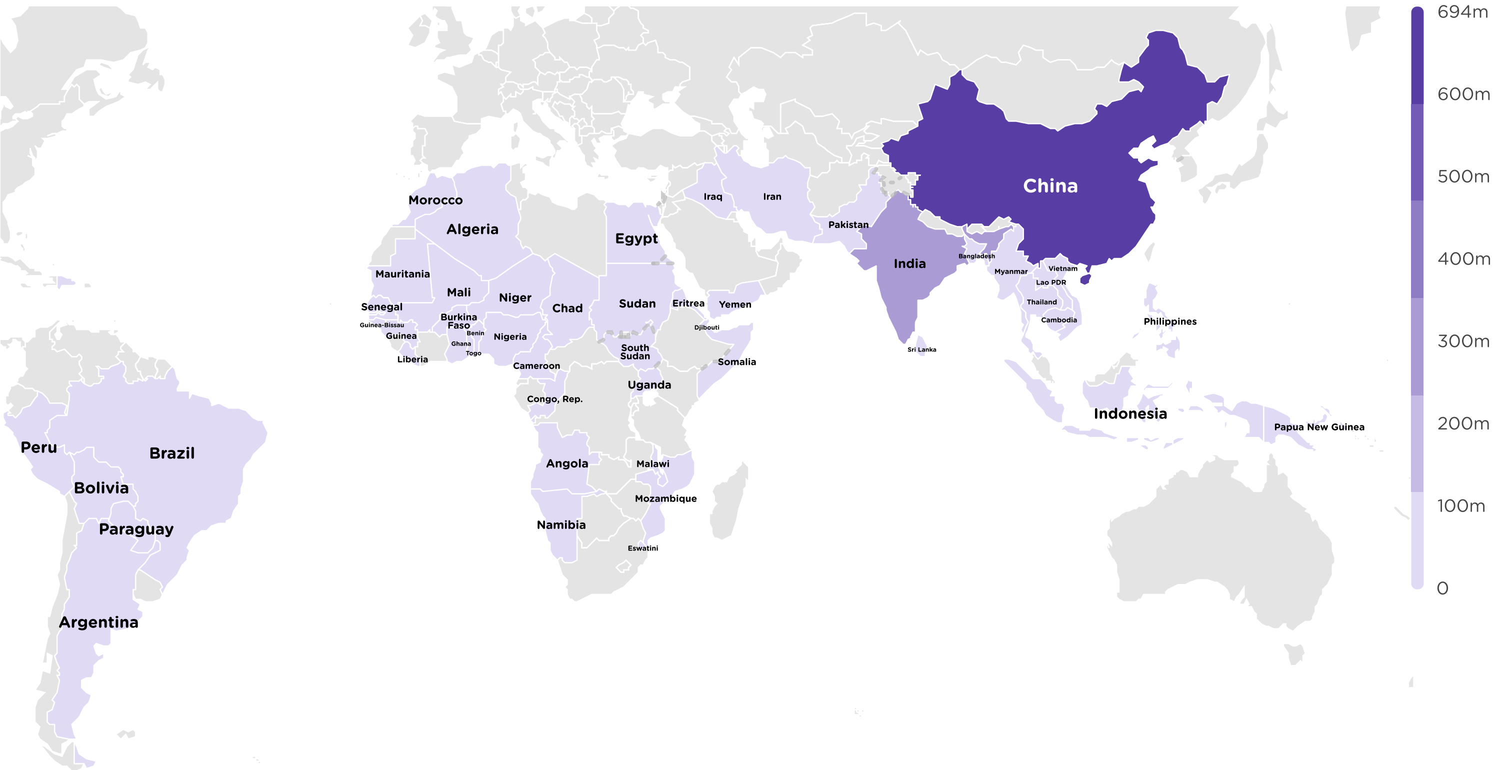
In Africa, the 31 high-impact countries considered in the analysis represent approximately 15 percent of the global total for the lower-middle-income population, increasing from 358.3 million to 361.1 million in the 2022 analysis. In absolute terms, Egypt and Nigeria represent the largest populations, with Algeria (28.3 million), Morocco (20.9 million) and Sudan (33.5 million) representing additional countries in Africa with over 20 million among the lower-middle-income population. In the Congo (DR), Guinea-Bissau, Mozambique and Somalia, the lower-middle income population is below 3 percent in each, reflective of persistent barriers to higher incomes and the access to cooling that is likely to come with it.

The high-impact countries in Asia and the Middle East include 81 percent of the global total for the lower-middle-income population, representing 1.94 billion people. The total lower-middle-income population in this region grew by almost 100 million compared to last year, and approximately 158 million people since 2020. The largest increases as a proportion of national populations are observed in Iran (13.4 percent), Sri Lanka, (9.6 percent), and Iraq (8.7 percent). All countries saw increases in their lower-middle-income populations, but the lowest observed increases occurred in Yemen (0.6 percent), Myanmar (1.2 percent) and Indonesia (2.2 percent).

In high-impact countries in Latin America and the Caribbean, the lower-middle-income population represents 3.7 percent of the global total, increasing by 6.6 million, from 81.4 million last year to 88 million in the 2022 analysis. Brazil accounts for the majority of the increase in absolute terms, with approximately 5 million more people among this group in 2022 compared to last year, with the number in Argentina increasing by 400,000 people and the number in Peru increasing by 130,000 people. Notably, Paraguay's lower-middle-income population decreased 3 percent compared to 2021.

1.3.4 Middle-income population at risk in 2022

FIGURE 1.14: MIDDLE-INCOME POPULATION BY COUNTRY AT RISK DUE TO A LACK OF ACCESS TO SUSTAINABLE COOLING



In high-impact countries, approximately 1.3 billion people typically own an air conditioner and a refrigerator and may be able to afford more efficient ones. They may also be able to move to better designed, more efficient housing and working environments, where they might also make conscious choices not to own an air-conditioning unit or minimize its use.

The middle-income segment of the population lives on between USD 10.01 and USD 20 per day. In high-impact countries, the middle-income population declined dramatically, by approximately 75.7 million, from 1.38 billion last year to 1.3 billion in the 2022 analysis. This follows a 79-million-person reduction from 2020, when the middle-income population stood at 1.46 billion globally. The number of people living on less than USD 20 per day in high-impact countries has seen an increasing trend in the last two decades. In 2022, this growth was offset by a sharper increase in the rural and urban poor as well as in lower-middle-income populations that was induced by the economic effects of the COVID-19 pandemic.

China continues to represent the highest middle-income population globally, with 693.3 million, or approximately 53 percent of the global total. The top five countries by absolute numbers, also including India, Brazil, Indonesia and Vietnam, represent approximately 81 percent of the global middle-income population. In both China and India, significant decreases in this population were observed, by almost 19 million in China and 45.2 million in India compared to last year, as the economic effects of the COVID-19 pandemic caused a significant shift towards the lower-middle-income segment, reversing a previously converging trend between the two risk groups. Notable proportional increases occurred in Benin (68.3 percent) and Uganda (54.4 percent), though in these countries the middle-income population experienced significant reductions of 51 percent and 30 percent, respectively, between 2020 and 2021.

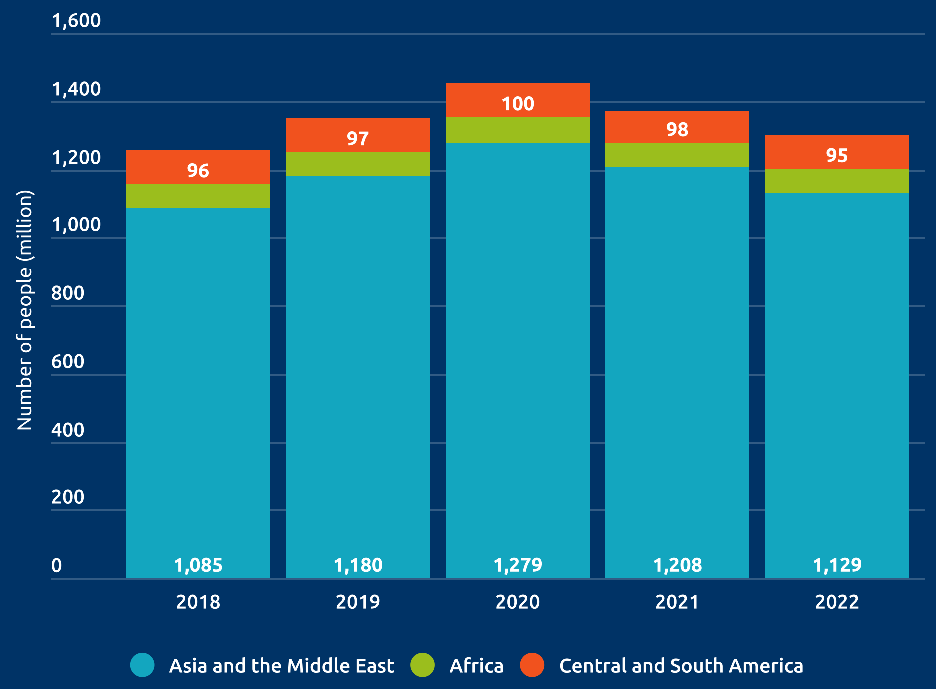
India, China and Brazil represented the top three countries in absolute numbers, although all top 10 countries saw a decrease in their middle-income population compared to last year. Overall, five countries saw a decrease in their middle-income population of 10 percent or more: Bangladesh, Djibouti, India, Myanmar and Pakistan.

TABLE 1.5: TOP 10 COUNTRIES WITH MIDDLE-INCOME POPULATION AT RISK (2020–22)

	2020	2021	2022
China	725,261,566	712,241,940	693,307,395
India	318,310,420	272,513,607	227,306,267
Brazil	64,264,579	62,936,482	60,261,319
Indonesia	50,255,168	50,008,731	48,598,522
Vietnam	31,881,715	31,590,145	30,841,096
Iran	31,826,441	31,682,494	29,656,560
Thailand	28,024,296	27,371,949	26,327,824
Philippines	23,408,611	23,571,453	23,311,908
Iraq	16,413,938	16,873,896	16,655,709
Algeria	15,297,402	15,586,133	15,002,517

Regionally, most of the middle-income population at risk are in high-impact countries in Asia and the Middle East.

FIGURE 1.15: REGIONAL BREAKDOWN OF MIDDLE-INCOME POPULATION (2018–2022 ANALYSIS)



The 31 high-impact countries in Africa are home to a middle-income population of 75.4 million people, or approximately 6 percent of the global total. This represents an increase of 7.1 million compared to last year, where Africa represented 4 percent of the total middle-income population. At 75.4 million, the middle-income population is now almost equivalent to pre-pandemic levels. Egypt and Uganda saw the largest increases in absolute terms, adding 2.3 million and 1.3 million to their respective middle-income populations compared to last year.

In Asia and the Middle East, the 16 high-impact countries for access to cooling account for 87 percent of the global middle-income population, though in absolute terms the population in the region declined by 79.3 million between last year and the 2022 analysis, from 1.21 billion to 1.13 billion. In addition to decreases in China and India, Pakistan's middle-income population decreased by 4.6 million people, a decline of 25 percent compared to 2021 and the highest proportional decrease in the region. Myanmar also experienced a 10 percent reduction in its middle-income population, from 5.4 million last year to 4.9 million in 2022. In Bangladesh, the middle-income population increased, but since 2020 the trend has reversed with lower-income groups accounting for most of the population at risk.

In Latin America and the Caribbean, the middle-income population decreased by 3.5 million, from 98.4 million last year to 94.9 million in 2022. This includes a 2.7-million-person reduction in Brazil and reductions of 500,000 and 155,000 people in Argentina and Peru respectively.

1.4 Populations at Risk in Countries Not Considered High Impact

Chilling Prospects 2021 included an analysis of the number of people at high risk due to a lack of access to sustainable cooling in countries not considered high impact, since localized heat vulnerability and lower socioeconomic status can create these risks even in middle-income or developed countries. Similarly, warming is not uniform within high-impact countries and regions, for example, approximately 42 million people in four high-impact countries (Argentina, Bolivia, China and Iran) live in regions where the threat of extreme heat is low, and hence they are less exposed to heat-related risks.

TABLE 1.6: POPULATION WITH ACCESS TO COOLING RISKS IN NON-HIGH-IMPACT COUNTRIES (2021–22 ANALYSIS)

	2021	2022	Change
Rural Poor	5,822,625	5,760,690	-61,936
Urban Poor	25,073,789	24,979,182	-94,606
Lower-middle Income	77,041,734	72,005,721	-5,036,013
Middle Income	64,564,370	63,577,570	-986,800

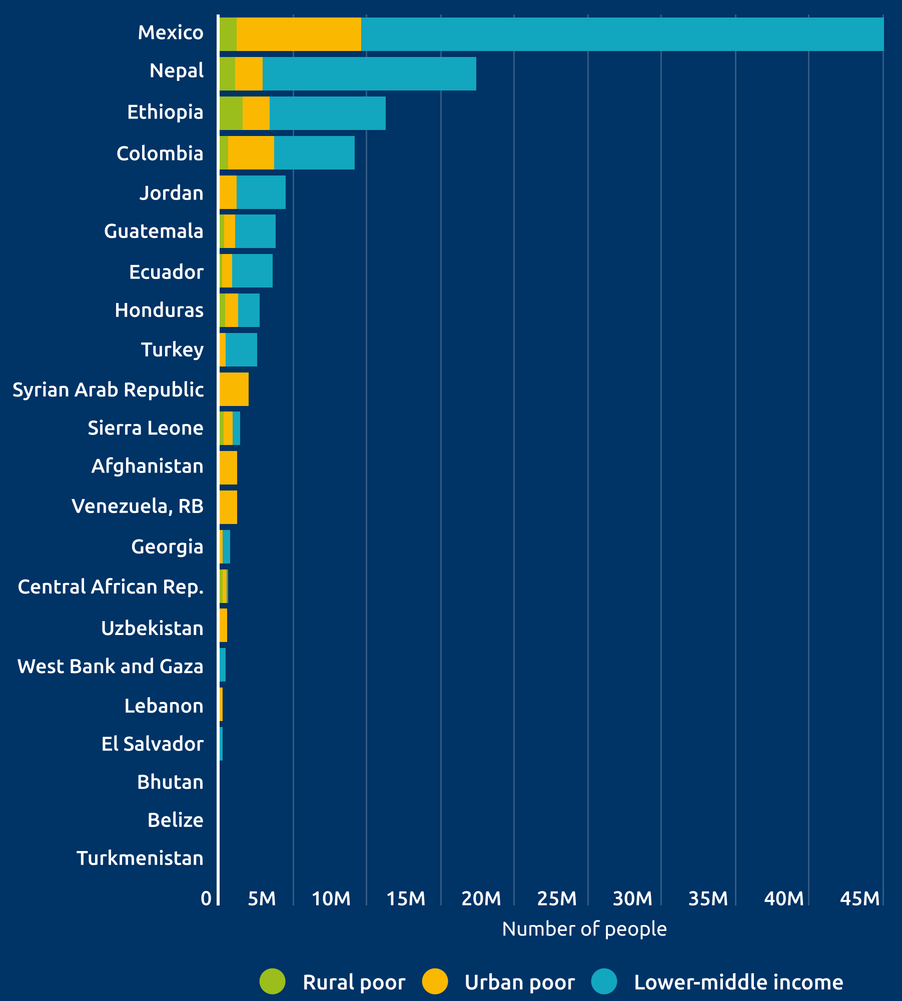
The 2022 analysis found that across the 22 countries not considered high impact,[13] but with regions that have extreme heat hazards, an additional 166.3 million people are estimated to be at risk due to a lack of access to affordable, sustainable cooling solutions.

This includes 30.7 million people at high risk in poor rural and urban areas, with 5.8 million among the rural poor and 25 million among the urban poor. Compared to last year, the number of rural poor in non-high-impact countries decreased by 61,900 people, while the number of urban poor decreased by 94,600 people. The most significant increase in the number of rural poor at risk among these countries was observed in Ethiopia, with an increase of 127,000 people at risk, while the largest decrease was observed in Nepal, with 311,000 fewer rural poor at risk. Nepal also saw the largest decrease in its urban poor, with 490,000 fewer people at risk, while Mexico had the largest increase, of approximately 293,000 additional urban poor at high risk.

In addition, 72 million lower-middle-income people and 63.5 million middle-income people living in high-temperature regions were found to have cooling access risks in the 22 non-high-impact countries. This represents a decrease of 5 million and 987,000 in the respective categories. Nepal again saw significant decreases across both categories, with 4.4 million fewer lower-middle-income people and 960,000 fewer people among its middle-income population. The most substantial increases were observed in Ethiopia and Mexico. Ethiopia saw an increase of 388,000 people in its lower-middle-income population and 348,000 in its middle-income population, while Mexico saw an increase of 706,000 and 869,000 to those populations respectively.

[13] Afghanistan, Belize, Bhutan, Central African Republic, Colombia, Ecuador, El Salvador, Ethiopia, Georgia, Guatemala, Honduras, Jordan, Lebanon, Mexico, Nepal, Sierra Leone, Syrian Arab Republic, Turkey, Turkmenistan, Uzbekistan, Venezuela and the West Bank and Gaza.

FIGURE 1.16: POPULATIONS AT RISK IN 22 NON-HIGH-IMPACT COUNTRIES



1.5 Projections of Access to Cooling in 2030

For the first time, *Chilling Prospects 2022* forecasts scenarios for populations at risk through to 2030. As global temperatures increase, together with the urgency to mitigate and adapt to climate change, demand for cooling will have wide-ranging effects on sustainable development outcomes. In hot countries, delivery of SDG7 and the ability of populations to realize the benefits of equitable and just energy transitions will depend significantly on our ability to close cooling access gaps substantially by 2030.

ACCESS TO COOLING AND RISK SCENARIOS IN 2030

Chilling Prospects 2022 projects global risk due to lack of access to sustainable cooling. It uses the 2022 analysis as its baseline, expressing it as year-end 2021 visually to support an understanding of progress expected to year-end 2030.

The projections through to 2030 consider three scenarios. The current trends scenario analyzes how risk related to lack of access to sustainable cooling may evolve between 2022 and 2030 if electricity access and extreme poverty continue to follow trajectories that are in line with current trends and, in the case of electricity access, with projections based on stated policies. The *SDG7.1* scenario analyzes how accelerating rural and urban electrification efforts in order to achieve *SDG7.1* would influence the populations at risk due to lack of cooling access. Finally, the *SDG7.1* and *SDG1.1* scenario explores how risk may change if universal access to electricity is achieved and, at the same time, extreme poverty is reduced to 3 percent or less of each country's population by 2030. All scenarios build on business-as-usual or middle projections for other factors that influence access to cooling and associated risks, such as population growth, urbanization, trends in the urban population living in slums, and projections of lower-middle- and middle-income populations. Further details are provided in the Annex.

HIGH RISK

The scenarios show that across the 54 high-impact countries and high-temperature regions of 22 countries not considered high impact, current trends would leave 1.22 billion people at high risk in 2030, compared to 1.2 billion in the 2022 analysis. This includes 1.18 billion people in high-impact countries and 43 million people in countries not considered high impact. If SDG7.1.1 and SDG1.1 are both achieved, the overall number of people at high risk decreases to 783.3 million — a 36 percent decline — including 745 million people in high-impact countries and 38.3 million people in countries not considered high impact. To reduce the number of people at risk further and ensure equitable access to sustainable cooling, SDG7.2, SDG7.3 and SDG13 will all need to be achieved.

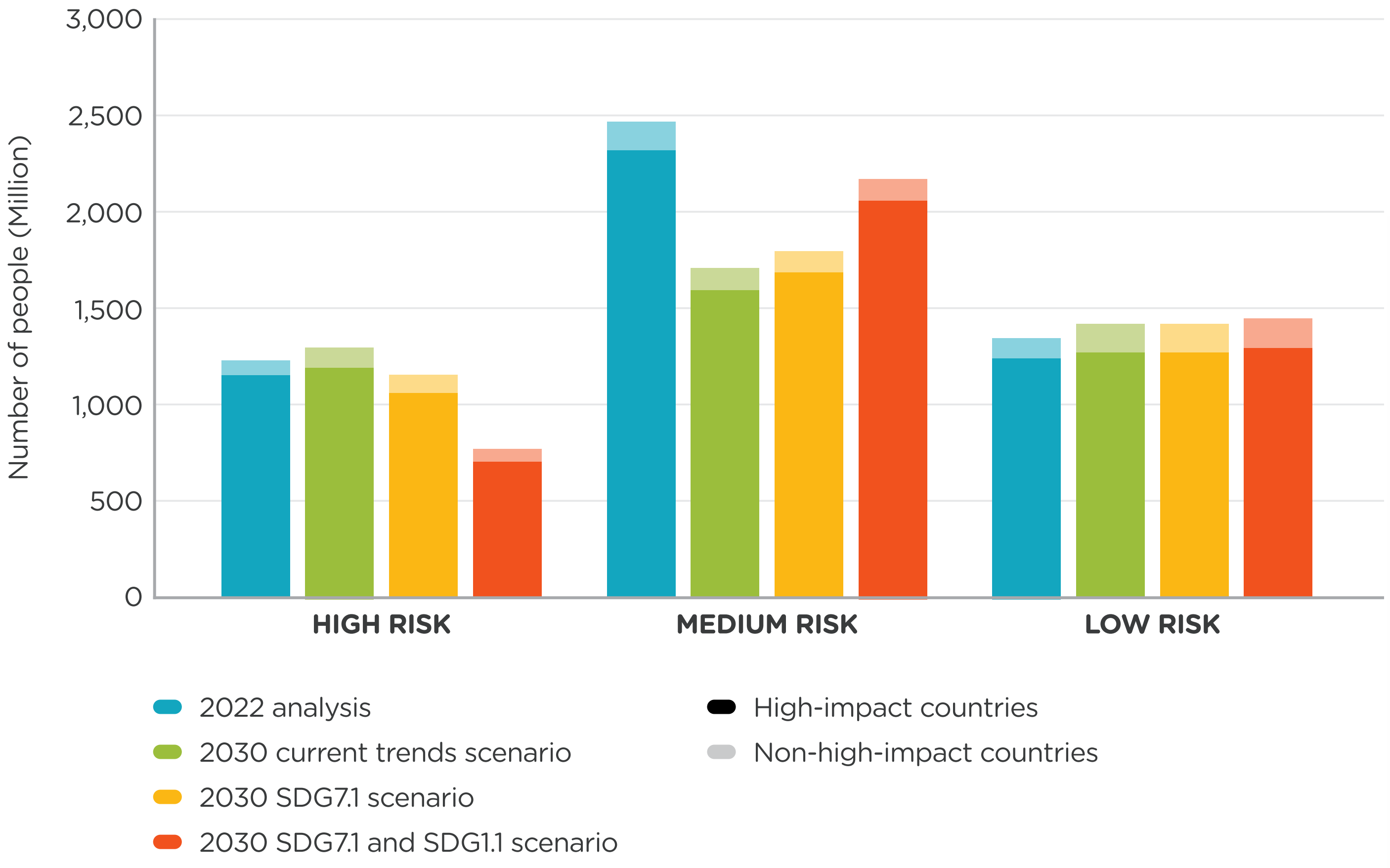
MEDIUM & LOW RISK

The scenarios underscore that ensuring those at medium and low risk have access to affordable and sustainable cooling solutions is imperative for sustainable energy systems and climate change goals. Under the current trends scenario, the lower-middle-income population (medium risk) will decrease to 1.72 billion people in 2030 across the 54 high-impact countries and high-temperature regions of 22 countries not considered high-impact. Achieving SDG7.1.1 and SDG1.1 by 2030 reduces this population compared to the 2022 analysis, though it remains higher than the current trends and SDG7.1.1. scenarios, likely due to a significant shift from the population at high risk owing to reductions in extreme poverty.

The middle-income (low-risk) population remains relatively stable under each scenario. Compared to the 2021 analysis, the middle-income population rises by approximately 95 million people compared to the 2022 analysis, to 1.46 billion in 2030 if SDG7.1.1 and SDG1.1 are achieved.

The sections that follow disaggregate the impacts of the three scenarios presented for the 54 high-impact countries and the high-temperature regions of 22 countries not considered high impact.

FIGURE 1.17: POPULATIONS AT RISK ACROSS ALL COUNTRIES IN THREE SCENARIOS (2022 ANALYSIS AND 2030 PROJECTED)



1.5.1 Cooling access gaps in 2030 in the 54 high-impact countries

Without climate change mitigation, the 54 high-impact countries are projected to have higher risks from unmet cooling needs in the coming decades, due to their increasing temperatures, frequency of days with dangerous heat, and a high number of cooling degree days (CDDs).[15] In these countries, the total population is projected to increase from 5.21 billion in 2021 to 5.66 billion in 2030. Within this, approximately 3.1 billion people among the high-impact countries will live in urban settings in 2030, compared to 2.6 billion in 2021, while approximately 2.5 billion people are expected to live in rural settings.[16] In addition, 235.7 million people in the 22 non-high-impact countries will live in regions with a high heat hazard level, with approximately 67 percent of these in urban areas. With growing urbanization and rural-urban migration, the size of the population living in urban slums is also expected to increase. In fact, SDG11.1 — to ensure access to adequate, safe and affordable housing — is one of the few SDG targets to have reversed its progress in recent years,[17] and it is estimated that the number of people living in slums in high-impact countries will grow from 808.1 million people in 2021 to 928 million in 2030.[18]

In this context, how demand for cooling is met — how fast, and with which solutions — will have a significant impact on efforts to end poverty (SDG1), achieve affordable, reliable, sustainable and modern energy for all (SDG7), and the achievement of several other SDGs.

This segment provides a projection of the populations at risk in high-impact countries due to lack of access to cooling under three scenarios: a current trends scenario, an SDG7.1 scenario (achieving universal access to electricity (SDG7.1.1), and an SDG7.1 & SDG1.1 scenario (achieving universal access to electricity in conjunction with eradicating extreme poverty. Achieving SDG7.1.1 (universal access to electricity) and SDG 1.1 (alleviating poverty) alone will not reduce all access to cooling risks, however it will contribute to a faster shift of populations to lower risk categories (Figure 1.17). Anticipating their role in delivering access to sustainable cooling, this section also describes the role of climate action (SDG13), increasing the share of renewable energy (SDG7.2), improving energy efficiency (SDG7.3), and the implementation of a climate-friendly refrigerant transition, as precursors to future analysis.

Access to cooling trends

The world remains off track to achieve universal access to electricity, and current trends in high-impact countries will result in 427 million people living without access to electricity in 2030, the majority of them in rural areas (369 million in 2030 compared to 363.6 million in 2021) and in Africa. Approximately 73.9 million people will not have access to electricity in urban areas, compared to 58.7 million in 2021.

[14] Measured by mean monthly temperatures of 30 degrees Celsius or higher.

[15] World Bank Climate Change Knowledge Portal. Link.

[16] World Bank Population Estimates and Projections, 2021.

[17] United Nations (2020) *Sustainable Development Goals Progress Chart.* Link.

[18] SEforALL projections, 2022.

Current trends projections for electricity access rely on a combination of historic trends in high-impact countries and the regional forecast under the International Energy Agency (IEA) *Stated Policies Scenario*.[19]

If poverty trends also continue in line with historical trends,[20] 473.9 million people are projected to live on USD 1.90 or less per day in high-impact countries in 2030[21,22]. This is a substantial reduction compared to 2021 (722.6 million), but far from the goal of eradicating extreme poverty. Following historical trends, the number of people living on USD 10.01 per day or less is projected to decrease from 3.56 billion in 2021 to 2.81 billion in 2030,[23] while the population living on USD 20 per day or less will go from 4.82 billion in 2021 to 4.18 billion in 2030.[24]

Under the ***current trends scenario***, the rural poor population at risk in high-impact countries reaches 306.8 million in 2030, a 17.3 percent decrease compared to the 2022 analysis, following a reduction in extreme poverty and electricity access gaps, together with a reduced rural population. Africa accounts for 65.4 percent of this population. Conversely, the urban poor population at risk grows to 871.9 million, a 6.9 percent increase compared to the 2022 analysis, driven by urbanization and increased risks posed by the urban heat island effect, (UHIE) a loss of heat sinks and informal housing. Asia and the Middle East will continue to account for approximately 63.8 percent of urban poor in 2030. Overall, as many as 1.18 billion people in poor rural and urban areas among the 54 high-impact countries are at high risk due to lack of cooling services to meet their needs for thermal comfort and safety, food security and health services in 2030, slightly above current levels. Critical 9 countries continue to account for most people at high risk (72.4 percent).

Over 1.7 billion lower-middle-income people in high-impact countries may be able to access some cooling solutions but will continue to face risks associated with limited options, particularly for high-humidity heat conditions, and options that are efficient and affordable. Although this is a substantial reduction compared to current levels (-30.6 percent), the lower-middle-income population remains the largest of the four groups of population at risk. Under the current trends scenario, the size of the middle-income population who may be able to access more efficient housing and working environments and to make conscious choices on the use of air-conditioning increases by 3.6 percent in 2030, reaching 1.35 billion people.

[19] IEA. 2022. SDG 7 Data and Projections, Access to Electricity. Link.

[20] Projections based on the Shared Socioeconomic Pathway scenario SSP 2 "Middle of the Road", further information is provided as Annex.

[21] World Poverty Clock. Link. Accessed April 2022

[22] Crespo Cuaresma (2020) Assessing Present and Future Global Poverty: Prospects and Challenges for Achieving Sdg1. Link

[23] IIASA, 2019.

[24] Poblete-Cazenave, M., Pachauri, S., Byers, E. et al. 2021. Global scenarios of household access to modern energy services under climate mitigation policy. Link

Achieving SDG7.1.1 — universal access to electricity — by 2030

This scenario examines the impact on cooling access gaps if SDG7.1.1 — universal access to electricity — is achieved in all high-impact countries in both rural and urban areas by 2030. The gaps to be filled in this scenario — and hence the challenge ahead — vary greatly among high-impact countries: while 21 high-impact countries had already reached over 90 percent electricity access in 2019, as many as 16 countries would have to improve their electricity access rates by more than 50 percent by 2030. The challenge is even more significant in rural areas, where 26 high-impact countries would have to improve rural electricity access rates by over 50 percent to meet SDG7.1.

While this scenario assumes universal access to electricity, it does not account for reductions in poverty necessary to achieve SDG1.1. Under the **SDG7.1 scenario** relatively small changes in the four risk groups for access to cooling are observed compared to current trends: overall, the number of people at high risk is reduced by 6.2 percent, while the number of lower-middle income people at risk increases by 4.2 percent. The only notable reduction is among the rural poor, which decreases by 17.1 percent compared to current trends, to 254.1 million people.

FIGURE 1.18: POPULATIONS AT RISK IN THE ACCESS TO COOLING CURRENT TRENDS SCENARIO (2021–2030)

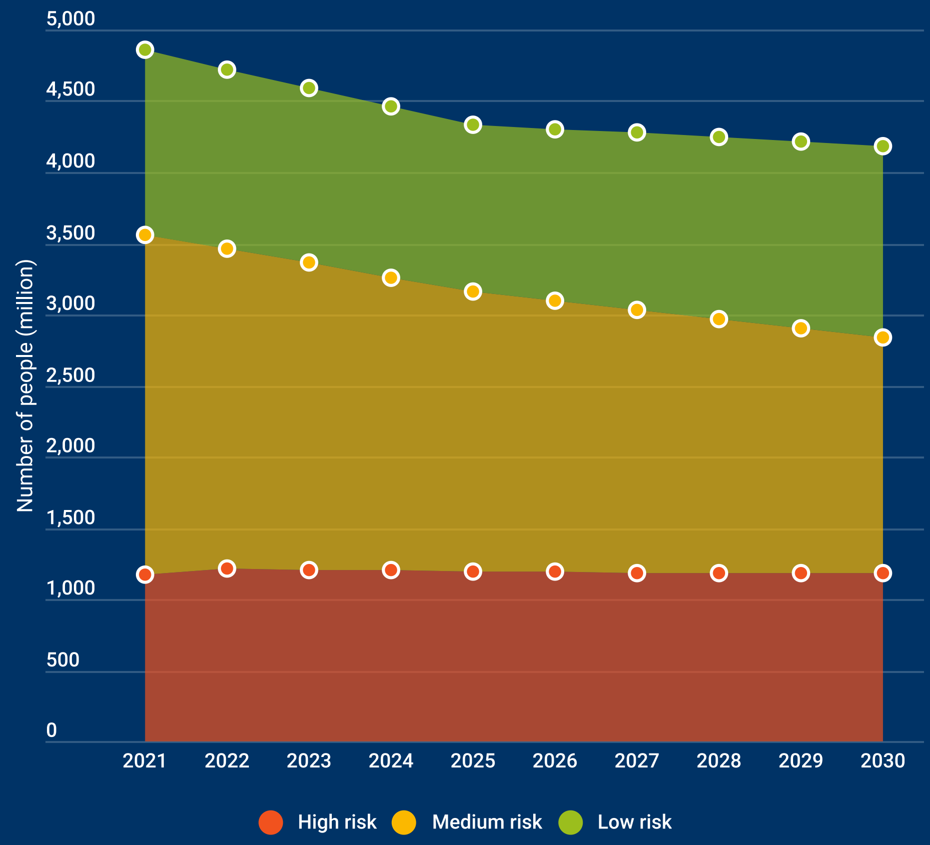
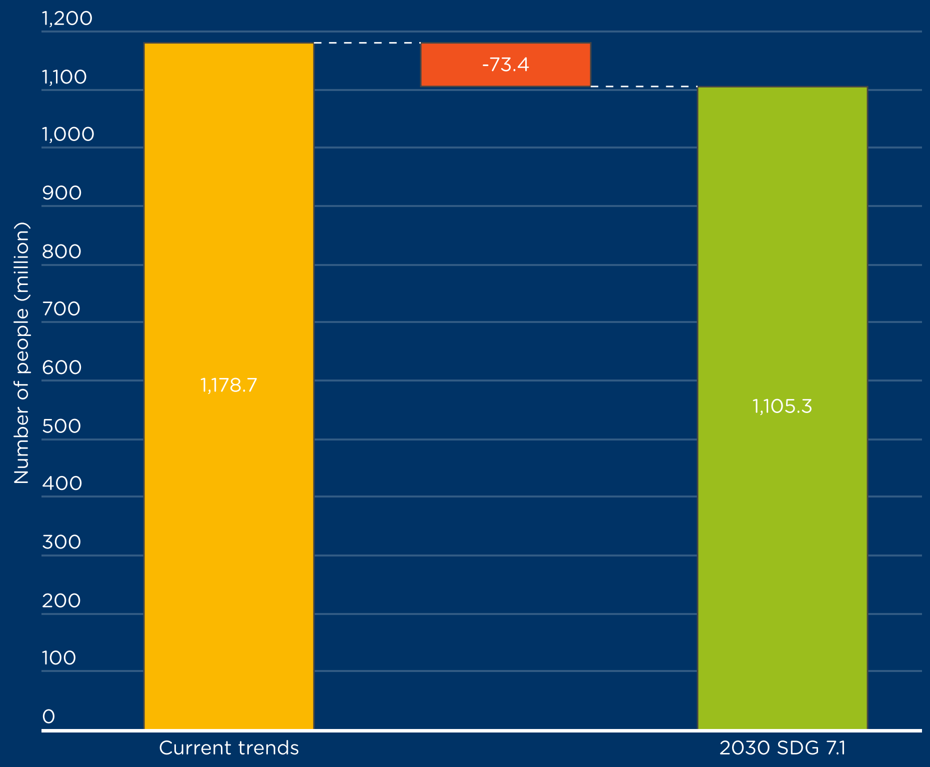


FIGURE 1.19: POPULATIONS AT HIGH RISK IN THE ACCESS TO COOLING SDG7.1 SCENARIO COMPARED TO CURRENT TRENDS



Achieving SDG7.1.1 — universal access to electricity — and SDG1.1 — eradicating extreme poverty — by 2030

This scenario assesses the impact on access to cooling gaps if efforts to close electricity access gaps are aligned with SDG7.1 and are accompanied by reductions of extreme poverty consistent with SDG1.1 (***SDG7.1 and SDG1.1 scenario***). The assessment shows that under this scenario, the overall number of people at high risk could decrease by almost 37 percent compared to current trends.

Currently, 21 of the 54 high-impact countries appear on track to reduce extreme poverty to 3 percent of their population or less in 2030. Sustainable Energy for All (SEforALL) projections show that, if the remaining 33 countries were also to accelerate progress towards SDG1.1. and reduce extreme poverty to 3 percent of their population by 2030, the number of people living on USD 1.90 per day or less would decline drastically to 102.4 million.

Under this scenario, the rural poor would see the most notable decrease, falling 87 percent by 2030, to less than 49 million people in high-impact countries. Unlike in other scenarios, the combined effects of electricity access and poverty reduction could outweigh the effects of urbanization, resulting in a 13 percent decrease in the urban poor population by 2030, from 796 million to 696.1 million in the high-impact countries. However, the reduction in risk for the poorest segments of the population is accompanied by a shift to larger lower-middle- and middle-income populations. Compared to the current trends and SDG7.1 scenarios, risk in lower-middle-income population declines less steeply in this scenario, by approximately -13.7 percent by 2030, reaching 2.07 billion people in 2030. Conversely, growth in the middle-income population accelerates slightly, by 5.7 percent by

2030, reaching 1.37 billion in 2030. The results point to the importance of income, and the fact that reducing access to cooling gaps for the most vulnerable depends on their ability to afford sustainable cooling solutions with access to a modern, reliable bundle of energy services as a prerequisite.

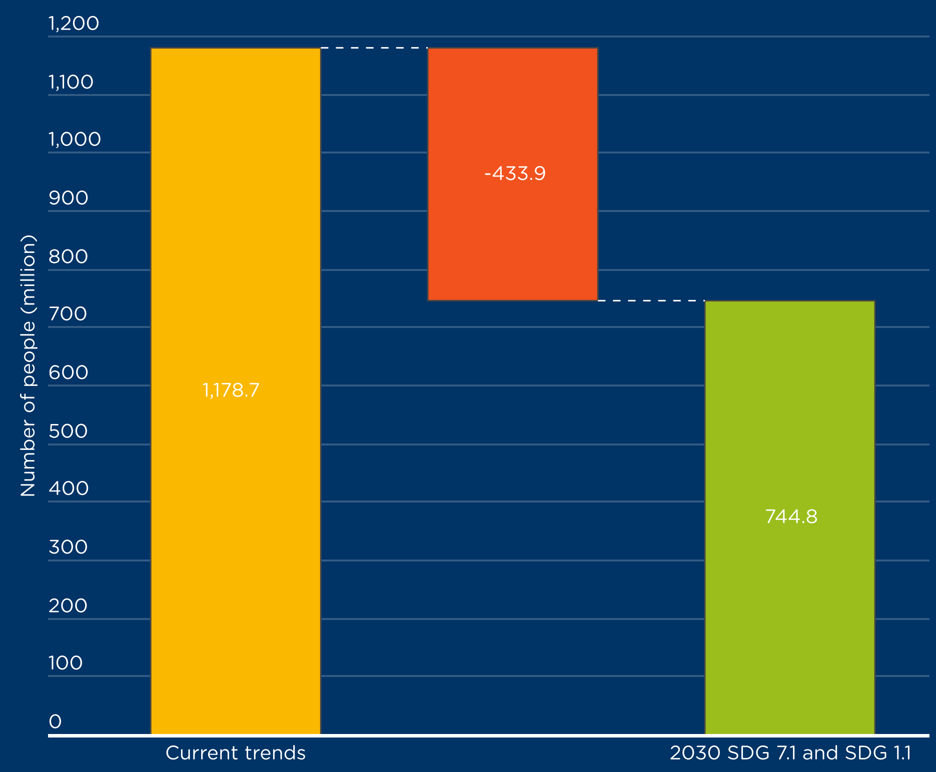
1.5.2 Cooling access risk in countries not considered high impact by 2030

The assessment also analyzed the impact of the three scenarios for populations at risk in the 22 countries that are not considered high impact, where cooling access risks are also expected to grow. By 2030, an additional 235.7 million people in these countries are projected to live in regions with a high heat hazard level, approximately 67 percent of them in urban areas.

Generally, similar trends are observed for these people under the three scenarios as those observed in the high-impact countries. Under the ***current trends scenario***, the non-high-impact countries would be home to approximately 188.2 million additional people at risk in 2030, an increase of 13.2 percent compared to the 2022 analysis. This includes increases in rural and urban poor populations at risk by 2.1 million and 10.2 million people respectively, resulting in over 43 million people facing high risk in 2030, a 40 percent increase compared to current levels. Under the ***SDG7.1 scenario***, the rural and urban poor at high risk in the non-high-impact countries would only be reduced by 0.5 percent compared to current trends.

However, reductions in risk are possible if universal access to electricity is achieved in combination with efforts to eradicate extreme poverty. In the ***SDG7.1 and SDG1.1 scenario***, the rural poor population at risk

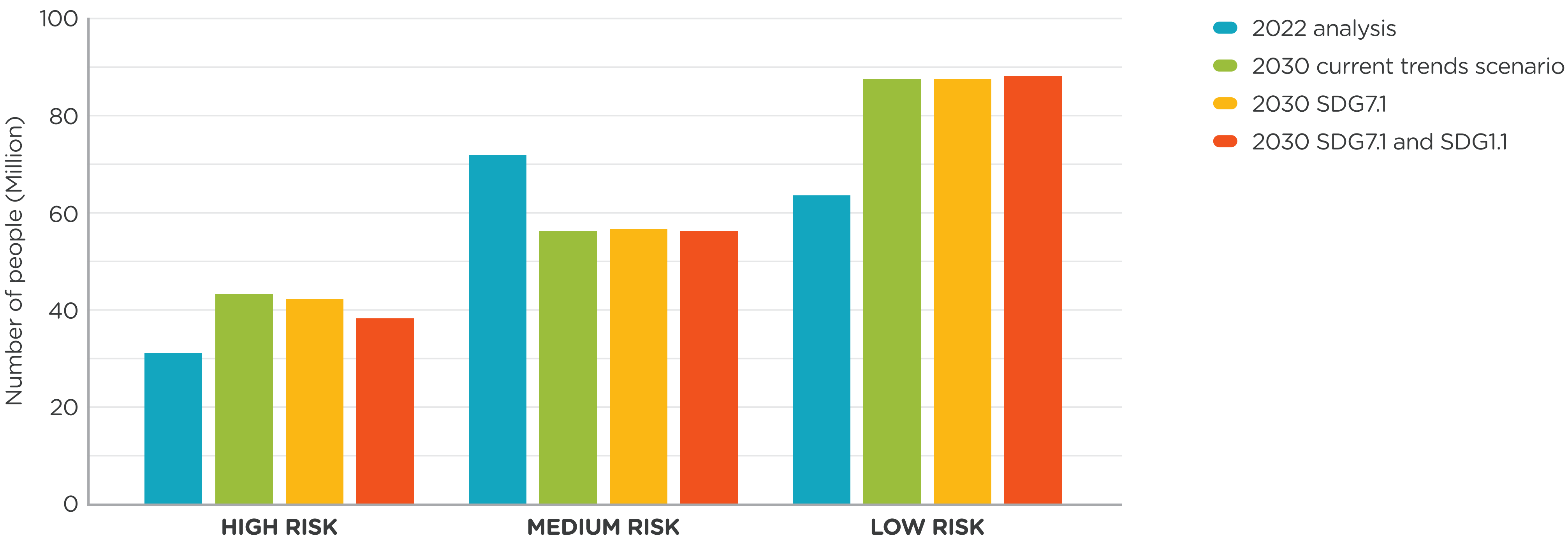
FIGURE 1.20: POPULATIONS AT HIGH RISK IN THE ACCESS TO COOLING SDG7.1 & SDG1.1 SCENARIO COMPARED TO CURRENT TRENDS



falls below current levels to 5.2 million people in 2030, and the urban poor population at risk falls to 33.2 million people. As a result, the population facing high risk in countries not considered high impact would be approximately 10.9 percent lower than under the current trends scenario.

The lower-middle-income and middle-income populations at risk do not vary substantially between the scenarios. The lower-middle-income population decreases from 72 million to 57.4 million people by 2030 in the SDG7.1 scenario, and to 57.1 million in the SDG7.1 and SDG1.1 scenario, reflecting part of the growth in the poorer segment of the population. By contrast, the middle-income population grows from 63.6 million currently to approximately 87.7 and 87.1 respectively.

FIGURE 1.21: POPULATIONS AT RISK ACROSS COUNTRIES NOT CONSIDERED HIGH IMPACT IN THREE SCENARIOS (2022 ANALYSIS AND 2030 PROJECTED)



1.6 The Role of Other Goals and Commitments on Sustainable Cooling

Achieving universal electricity access (SDG7.1.1) and eradicating extreme poverty (SDG1.1) by 2030 will be critical in reducing the number of people at high risk due to a lack of access to cooling. However, there is a need to further understand the role of SDG7.1 (including the quality of electricity access) and the role of SDG7.2 (substantially increasing the share of renewable energy by 2030), SDG7.3 (doubling of energy efficiency by 2030) and SDG13 (climate action) on access to cooling risks. All these factors are not currently factored into the gap analysis and will affect how cooling access needs are met and the impact that they will have on people, products and the planet.

1.6.1 The role of access to modern energy (SDG7.1) on sustainable cooling

Further analysis is needed to better understand the cooling solutions that can be made accessible to populations at risk, and their impact on reducing cooling access gaps. This analysis would build on the World Bank Multi-Tier Framework for understanding access to energy, where those with the lowest tier of access to energy will not have full access to sustainable cooling solutions. As people gain higher quality electricity access and increase their income levels, ownership rates of cooling solutions such as fans and refrigerators can be expected to increase. The affordability of efficient solutions that can be powered at lower tiers of energy access will therefore be important to bridging the cooling gap and accelerating uptake of sustainable cooling solutions. This is particularly important for off-grid consumers, with initial research from SEforALL and its partners pointing to the increasing viability of sustainable solutions at lower tiers of electricity access.[25]

1.6.2 The role of renewable energy (SDG7.2) on sustainable cooling

At present most cooling needs are met with active solutions (fans, air conditioners, refrigerators, cold storage, etc.) that require electricity to operate. Most electricity supply in developing countries is generated using fossil fuels and as such active cooling can be highly carbon intensive. However, increasing the renewable energy share in the grid and coupling cooling demand with renewable energy generation would have a major role in decarbonizing the cooling sector.

Unlike the space-heating sector, space cooling is not commonly centralized or serviced by district energy, and the lack of this scale of energy-service architecture creates barriers to leveraging large-scale variable renewable energy to power cooling demand. The potential of deploying renewable energy for sustainable-cooling access is immense, particularly for the rural poor living in off-grid settings. Electricity access delivered with decentralized renewables can support access to sustainable cooling as well as improve the livelihoods of farmers through productive uses of energy that include cooling. Achieving SDG7.2 by 2030 is therefore expected to play a key role in deploying sustainable solutions for different cooling needs and the impact of the effect of this on reducing cooling access gaps will be explored further in the future.

1.6.3 The role of energy efficiency (SDG7.3) on sustainable cooling

Energy efficiency is pivotal for the cooling sector to support climate and development goals. Cooling-appliance ownership is a major way to reduce risks faced by rural and urban populations, but low efficiency standards for cooling appliances can contribute to energy-demand growth, increased emissions, and reduced household-purchasing power. Conversely, stronger energy-efficiency standards for cooling appliances can reduce cooling access risks by making operating costs affordable, reducing energy bills, and spreading available grid capacity to serve a wider section of the population. As such achieving SDG7.3 in the cooling sector is not only critical for climate action, but also for ensuring that the multiple benefits of energy efficiency enable the achievement of other SDGs.

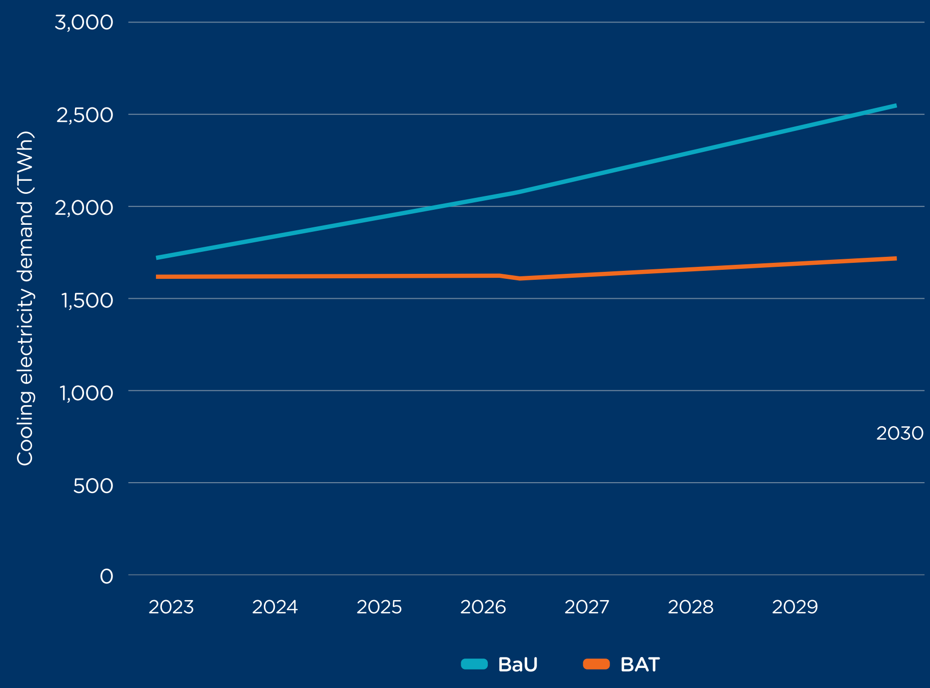
With further analysis of energy efficiency there are two main interventions that would need to be assessed for their contribution to reducing access to cooling gaps – the impact of active

and passive solutions. Energy-efficiency standards for active cooling coupled with passive solutions have the potential to drastically change the energy demand by 2030 and reduce carbon emissions.

The first energy-efficiency strategy should be to reduce the need for active solutions through the deployment of passive cooling. One example is by leveraging passive solutions for energy efficiency and thermal efficiency in the buildings, storage and vehicles where energy needs for active cooling can be reduced significantly. Also, passive strategies in built environments and farms, such as nature-based solutions, can provide the first level of heat stress relief through shade and natural cooling. These passive strategies lead to meaningful reductions in the UHIE, further reducing the need for active cooling and optimizing how and when energy-based active solutions are used. The need for this holistic approach and optimization with passive cooling will only become more important with rapid urbanization and growing heat islands that make all urban residents more vulnerable to the impacts of extreme heat.

Active solutions, such as energy efficient air conditioners, fans and refrigerators, would need to be made affordable compared to inefficient alternatives through policies (e.g., minimum energy performance standards (MEPs) and labels) and market mechanisms to increase their supply, lower up-front costs and mainstream their adoption through addressing up-front-cost and information barriers. Air conditioners and fans already account for 20 percent of the total electricity demand in buildings globally and doubling their efficiency levels could reduce the energy demand in buildings for space cooling by 45 percent.[26]

FIGURE 1.22: ELECTRICITY DEMAND FOR ACTIVE COOLING IN HIGH-IMPACT COUNTRIES UNDER A BUSINESS- AS-USUAL SCENARIO OR WITH BEST AVAILABLE TECHNOLOGY (2023-2030)



Source: The Appliance & Equipment Climate Impact Calculator, CLASP, V1.2, February 2022, https://clasp.shinyapps.io/mepsy. (2022)

[26] IEA Future of Cooling, 2018

1.6.4 The role of sustainable cooling on climate action (SDG13)

Further analysis is needed based on scenarios for SDG7.2 and SDG7.3, in addition to the SDG7.1 and SDG1.1 scenarios, to understand the climate action (SDG13) implications of cooling needs in terms of the impacts on energy demand and the resulting carbon emissions. Closing cooling access gaps with sustainable cooling solutions is critical for the cooling sector to be in line with Paris Agreement goals. Further analysis can also support a better understanding on which populations are able to have reduced heat-related risks under different emissions pathways.

In a business-as-usual scenario, cooling demand from mechanical solutions such as air-conditioning and refrigeration alone is expected to result in 12 GtCO2eq by 2050, which would be equivalent to one-third of global carbon emissions in 2017.[27] The year 2030 is an important milestone for climate action, since the pathway to achieving the Paris Agreement requires achieving a 45 percent emissions reduction by 2030.[28] To ensure efforts to deliver access to cooling are consistent with the SDGs and the Paris Agreement, efforts must also align with this emissions reduction target.

1.6.5 The role of achieving the Montreal Protocol on sustainable cooling

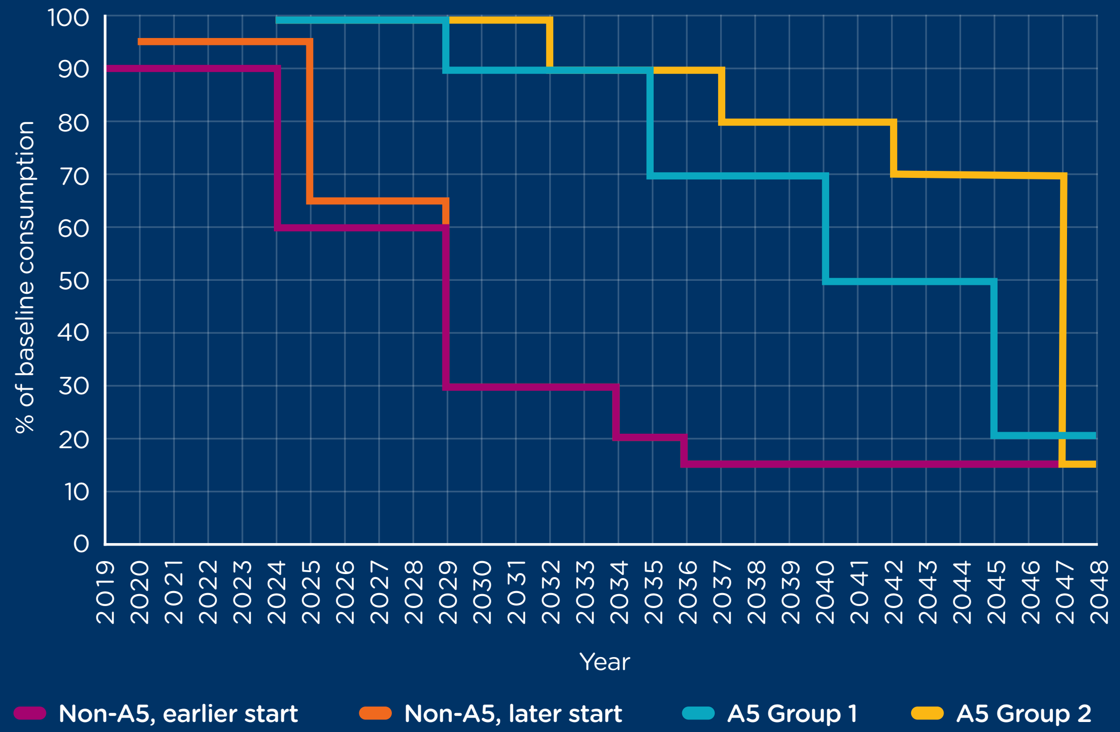
The Montreal Protocol is an international treaty designed to protect the ozone layer, and the Kigali Amendment pushes one step further to reduce the impact from hydrofluorocarbons (HFCs). Refrigerants are considered the blood of refrigeration and air-conditioning systems. However, synthetic refrigerants, historically mainly chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and HFCs have had significant impacts on ozone and climate. The Kigali Amendment also promotes energy-efficiency opportunities (supporting SDG7.3) that can be leveraged with the climate-friendly refrigerant transition and is estimated to have the potential to avoid a temperature rise of up to 0.4°C by 2100.[29]

[27] Climate and Clean Air Coalition, Efficient Cooling.

[28] IPCC Special Report: Global Warming of 1.5°C

[29] IEA, Cooling Emission and Policy Synthesis Report, 2020

FIGURE 1.23: KIGALI AMENDMENT HFC PHASE-DOWN SCHEDULES



Source: http://www.unep.fr/ozonaction/information/mmcfiles/7876-eKigali_FS01_Introduction.pdf
(accessed 13 December 2018)

Climate-friendly refrigerant transitions are happening on different timelines for developed and developing countries, given their differing economic status and market readiness levels to adopt new technologies. Developed countries, for example, are only expected to freeze their HFC consumption level from 2024, with the first phase-down step expected in 2029 and the final phasedown completed by 2047. Given the implementation schedule of the climate-friendly refrigerant transition, it will be important to consider the impact of the Kigali Amendment on the availability and affordability of sustainable cooling solutions for vulnerable groups, along with universal electricity access, renewable energy and energy efficiency.

CHILLING PROSPECTS

CHAPTER TWO

Access to Cooling Needs – Data & Trends

Access to sustainable cooling underpins the delivery of important components of several of the Sustainable Development Goals (SDGs), those addressing poverty (SDG1), hunger (SDG2), health and well-being (SDG3), affordable and clean energy (SDG7), employment (SDG8), and sustainable cities and communities (SDG11). In partnership with the Cool Coalition, the World Bank Energy Sector Management Assistance Program (ESMAP) and the University of Birmingham, among others have advocated for a needs-based approach to delivering access to cooling across three core needs that contribute to the SDGs: food, nutrition and agriculture; health services; and human comfort and safety. This chapter provides an update on new data related to these needs, as well as a general review of how action in these areas contributes to enhanced access to sustainable cooling solutions.

2.1 Food, Nutrition and Agriculture

The cost of food loss and waste is estimated at nearly USD 1 trillion annually. Food is lost and wasted throughout various stages of the food supply chain, with 14 percent of all food produced lost between harvest and retail, and 17 percent of all food produced wasted in households, restaurants and across other food services.[1,2] If food loss and waste were a country, it would be the third biggest emitter of carbon on the planet, at more than 3 billion tonnes of greenhouse gases (GHGs).[3] A 2018 study estimates that this figure will grow, with food loss and waste amounting to 2.1 billion tons of food annually, a global economic loss of USD 1.5 trillion in 2030 in a business-as-usual scenario.[4]

Access to sustainable cooling is a key enabler for solving these challenges and achieving SDG2 for the over 800 million people who suffer from hunger. It is estimated that a lack of sustainable cold chains, including freezers and refrigeration, directly results in 526 million tons of food production loss every year,[5] a factor that also contributes to the 15 percent reduction in smallholder farmers' income.[6] Access to sustainable cooling is also closely linked to SDG7 since access to affordable and clean energy underpins the ability to access refrigeration and to move to more efficient and scalable food production.

In rural areas without access to affordable, reliable, and sustainable energy, expanding cooling infrastructure for agricultural purposes is a significant challenge. By expanding access however, sustainable cooling solutions for food and agriculture can enable emissions reductions and the productive use of energy, for example through shifts in production to perishable crops that can be sold at higher prices in more distant markets.

[1] FAO (2021). Transform food systems to avert $400 billion annually in loss and waste. Link.

[2] FAO (2014). Food Wastage Footprint: Full-cost Accounting. Final Report. Rome. Link.

[3] FAO (2021). Transform food systems to avert $400 billion annually in loss and waste. Link.

[4] Boston Consulting Group (2018). Tackling the 1.6-Billion-Ton Food Loss and Waste Crisis. Link.

[5] Sarr, J et al. "The Carbon Footprint of the Cold Chain, 7th Informatory Note on Refrigeration and Food." IIR, 2021, Link.

[6] Peters, T, Leyla Sayin, et al. (2021). Status of the Global Food Cold Chain: Summary Briefing. Cool Coalition. Link.

For many food products, access to refrigeration is crucial to limiting food loss and to keeping produce as close to its post-harvest state as possible. Agricultural cold chains consist of several components, typically at least pre-cooling, cold storage and refrigerated transport (Figure 2.1).

FIGURE 2.1: THE CONNECTION BETWEEN THE FOOD SUPPLY CHAIN AND COLD CHAIN

Pre-cooling — Production
Prevents fast degradation of many perishable foods

→ **Pre-cooling or bulk storage** — Processing
Increases product quality and shelf life

→ **Retail cooling** — Distribution
Maintains quality of produces during transportation and interconnects all stages of the cold chain

→ **Household refrigeration** — Consumption
Limits food spoilage and food poisioning and increases access to nutritious food

Source: Norne Widel et al. (2019)

Global food loss and waste trends

There are two primary issues in sustainable food systems: food loss and food waste. Food waste occurs at the retail or consumer level, where it is wasted due to behaviour, including storage, purchasing and consumption patterns, predominantly in high-income countries. It can also occur due to a lack of access to affordable refrigeration, causing spoilage, a loss of nutritional value and food safety issues. However, the link between a lack of access to refrigeration and food wastage is largely intuitive and lacks reliable data for analysis; as a result, the analysis in this section focuses on food loss and the data available to understand its links to a lack of access to cooling.

Food loss can be understood as damage and spoiling that occurs in the supply chain, with one of the primary drivers being a lack of appropriate temperature and humidity management during post-harvest: packaging, storage and transportation. In low-income countries, food loss in the supply chain is a major challenge, occurring mainly due to a lack of harvesting and processing capacity, as well as poorly functioning or non-existent cold

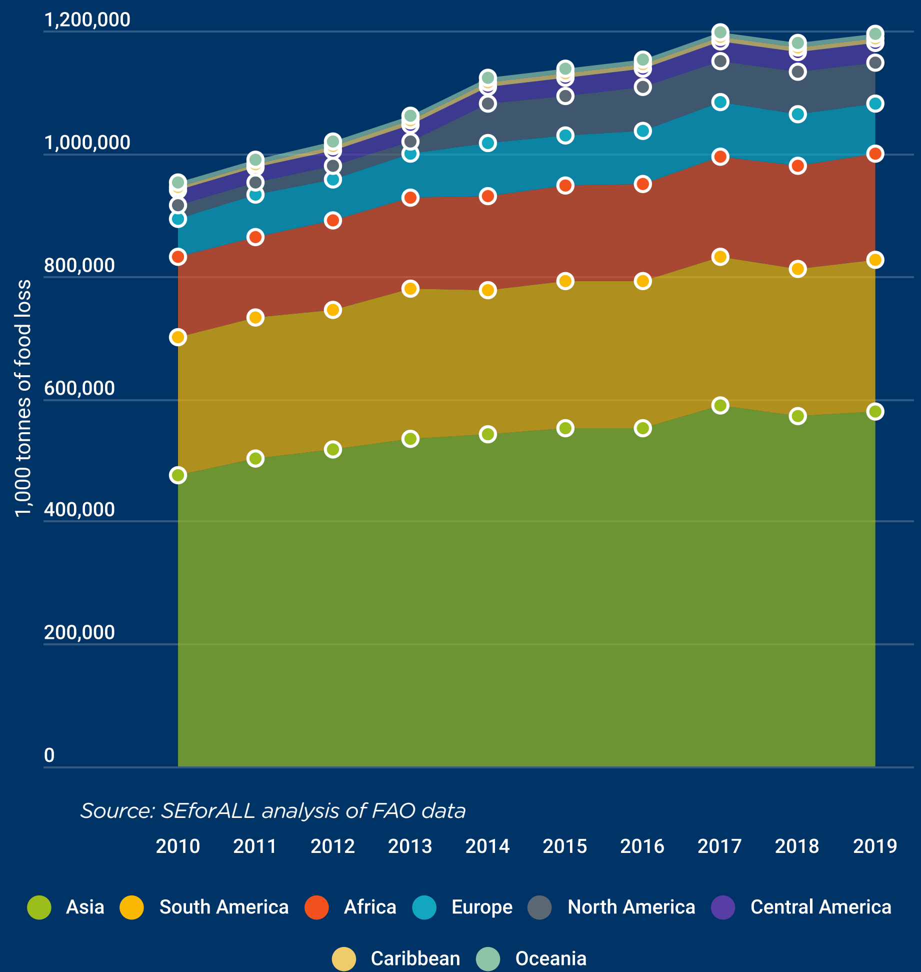
chains.[7] Most countries with electricity access gaps have challenges establishing reliable cold chain infrastructure.[8] It has been observed that access to reliable and affordable electricity can improve agricultural yield[9] but the lack of cold chain results in significant post-harvest losses and loss of significant economic value.

Global trends show an average 3 percent annual increase in food loss from 2010 to 2019 (Figure 2.2)[10] with global total food loss (including non-perishables) in 2019 at a staggering 1.2 billion tonnes of food, equivalent to more than three times the food production of Africa annually.

Global food loss is concentrated mainly in Asia, South America and Africa (Figure 2.2). At 48 percent, Asia has the highest food loss share. Each region's share has remained largely the same except for North America, where it has tripled since 2013.

Food loss in low-income food deficit countries accounts for about 22 percent of the world's total food loss and has consistently increased over the past decade, widening the food supply gap for large sections of vulnerable populations (Figure 2.3).

FIGURE 2.2: GLOBAL FOOD LOSS TRENDS (2010-2019)



Source: SEforALL analysis of FAO data

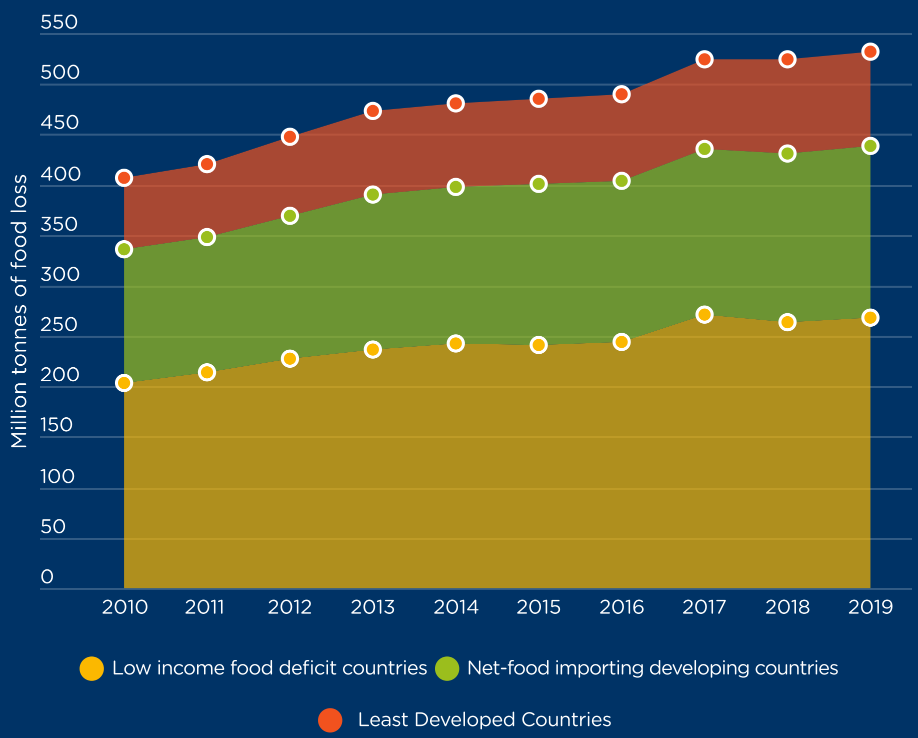
[7] Norne Widell K. et al. (2019). Refrigeration to prevent food losses. Link.

[8] FAO (2021), Transforming food value chains: sustainable cooling solutions for agricultural cold chains. Link.

[9] Shirley R. et al. (2021). Identifying high-priority impact areas for electricity service to farmlands in Uganda through geospatial mapping. Journal of Agriculture and Food Research, Volume 5. Link.

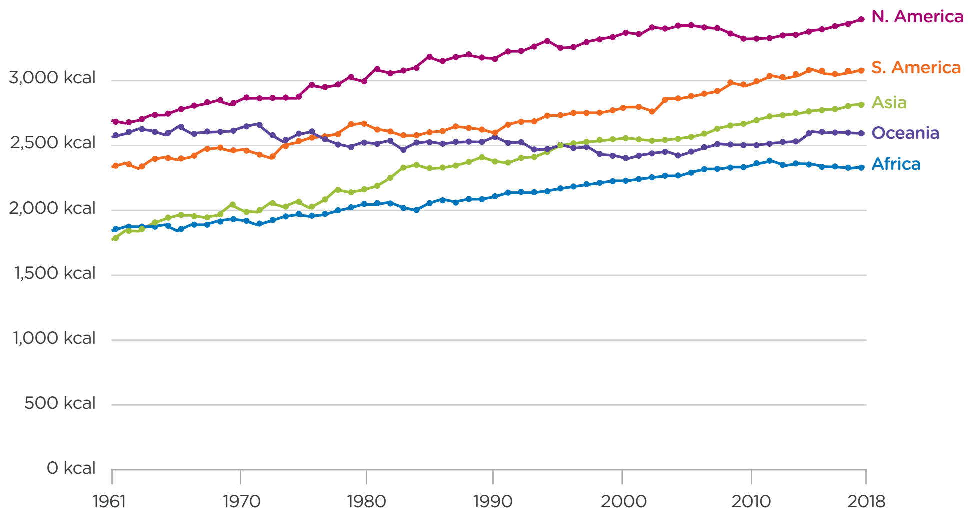
[10] FAO perishable food loss data for dairy, meat and horticulture (vegetables and fruits). No data available on seafood loss.

FIGURE 2.3: FOOD LOSS TRENDS AMONG THE MOST VULNERABLE COUNTRIES (2010–2019)



Source: SEforALL analysis of FAO data

FIGURE 2.4: FOOD SUPPLY TRENDS (KCAL PER PERSON/DAY)



Source: Our world in data and FAO

Food loss and trends in high-impact countries

Access to reliable cold chain at farms and improved refrigerator affordability can support a reduction of food loss, improved food security and higher incomes for people working in agriculture and food service jobs. However, having access to reliable and sustainable electricity and higher income levels for the poor, particularly women, is crucial for meeting nutritional standards, even with an increased supply of food.

The 54 high-impact countries for access to cooling[11] include 31 countries in Africa, 16 in Asia and the Middle East, six in Latin America

[11] The Cooling for All high-impact countries for access to cooling, identified each year in Chilling Prospects, are those countries that have a combination of economic, climate and population conditions that place a significant portion of the population at risk due to a lack of access to cooling.

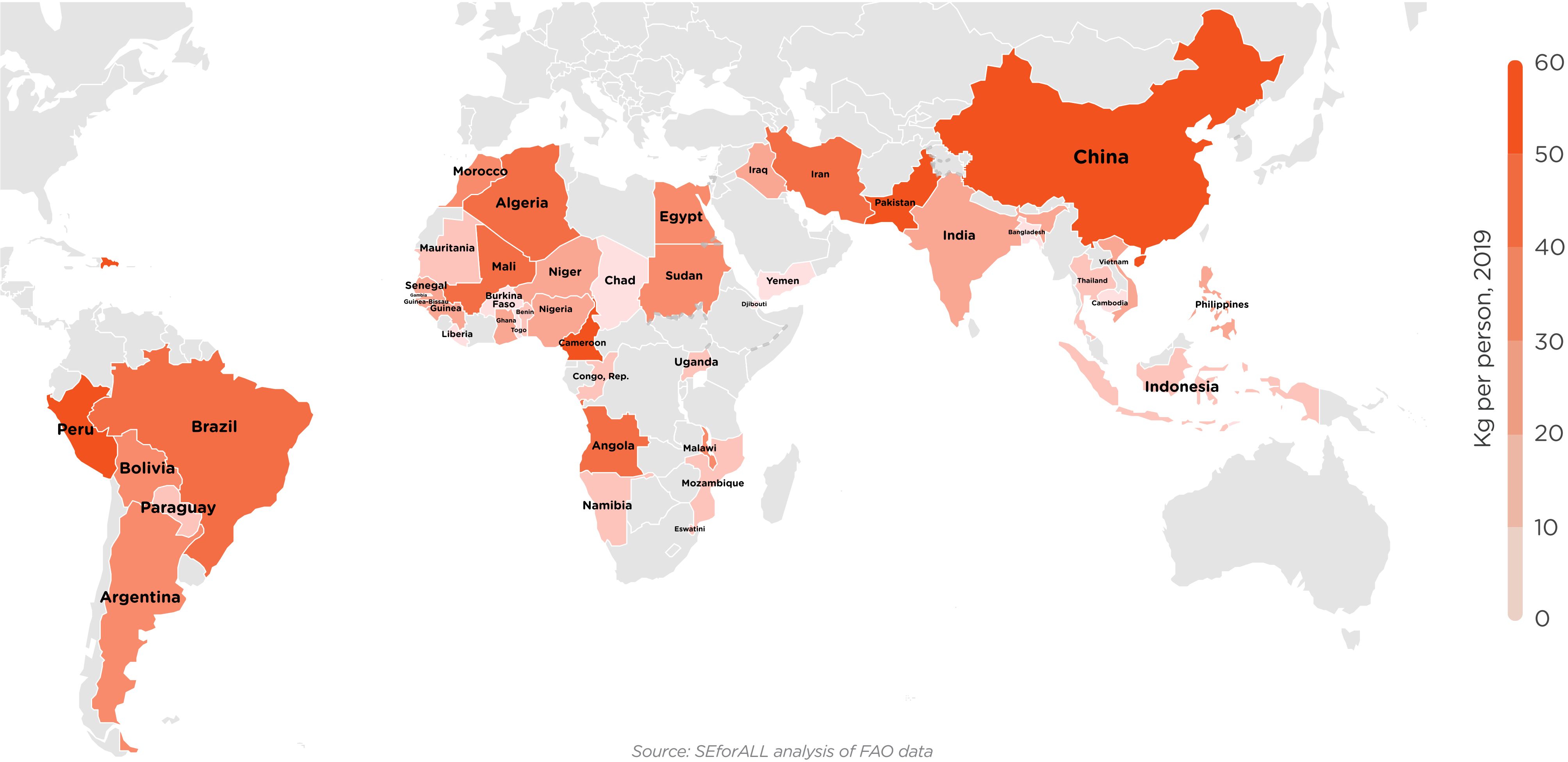
and the Caribbean, and one in the Oceania region. An analysis of the volume of perishable food losses among these high-impact countries shows that more than 50 percent of the losses occur in China, followed by India (17 percent), Pakistan (7 percent) and Brazil (6 percent). Out of the 31 high-impact African countries, only two (Egypt and Nigeria) have food loss shares of more than 2 percent each (Figure 2.5). The food loss percentage discrepancy in Africa in comparison to Asia and the Middle East is due to food loss being distributed across a greater number of countries, and the fact that the population of the countries in Asia and the Middle East, especially China and India, is far more than that of all the African countries combined.

The impact of food loss on vulnerable populations is more evident when assessing the per-person food losses in high-impact countries. The average food loss is 35 kg per person per year and losses range between 3.8 kg to 62 kg per person in the 54 high-impact countries. Data show that Cameroon, China, the Dominican Republic, Pakistan and Peru are on the high end of that scale (Figure 2.6).

FIGURE 2.5: SHARE OF FOOD LOSSES IN HIGH-IMPACT COUNTRIES FOR ACCESS TO COOLING

Source: SEforALL analysis of FAO data

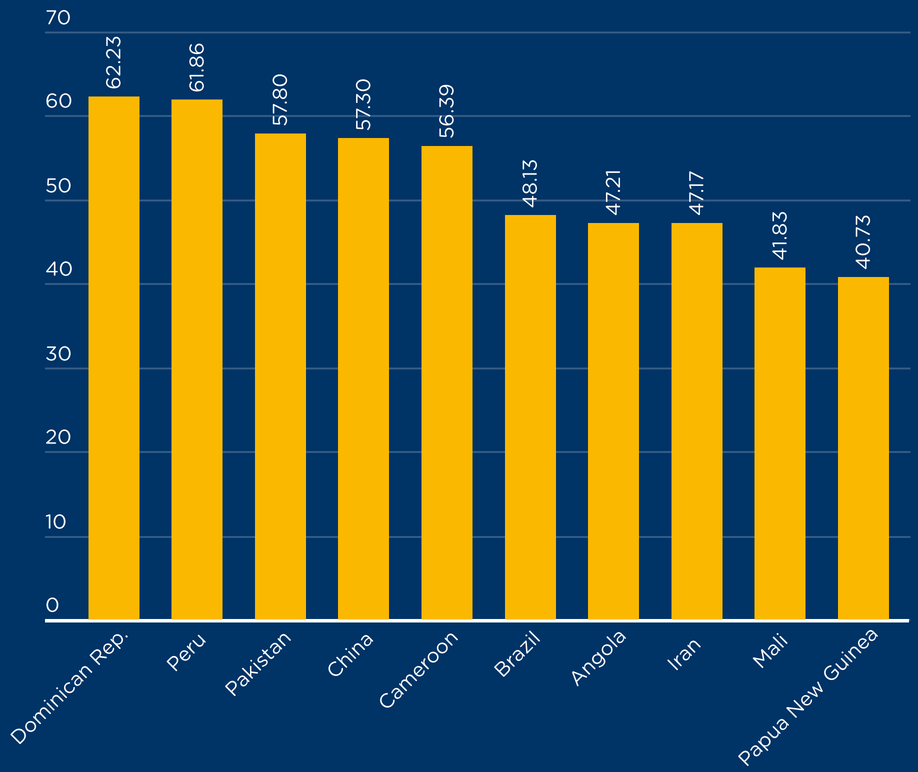
FIGURE 2.6: FOOD LOSSES PER PERSON IN HIGH-IMPACT COUNTRIES FOR ACCESS TO COOLING (KG/PER CAPITA)



Source: SEforALL analysis of FAO data

In China and India, where food losses are highest by volume, per-capita losses are 57.3 kg and 21.6 kg respectively, while the Dominican Republic and Peru record the highest per-capita food losses, both with over 60 kg per capita. Among the 10 high-impact countries with highest food losses per person, four are in Africa – Angola, Cameroon, Mali and Papua New Guinea (Figure 2.7).

FIGURE 2.7: TOP 10 PER-PERSON FOOD LOSSES IN THE 54 HIGH-IMPACT COUNTRIES FOR ACCESS TO COOLING



Source: SEforALL analysis of FAO data

Reducing the loss of perishable food through adequate cold chain infrastructure and efficient supply chains can reduce the vulnerabilities of least developed countries (LDCs) caused by food supply. For instance, LDCs[12] have an annual average food supply of 505 kg per person,[13] and reducing the loss of perishable food in these countries can improve the necessary dietary nutrient supply available for their vulnerable populations.

Energy use and climate impact due to food production and loss

The production and supply of food is a process that uses a significant amount of energy and is a notable source of GHG emissions. Closing cooling access gaps in the agricultural sector through cooling efficiency improvements, an expansion of sustainable energy technology, and Kigali-compliant refrigerants, could avoid 55 percent of food losses experienced now and reduce cold chain emissions by 55 percent.[14]

On farms, for example, the use of electricity is necessary for pumps, packing houses and cold storage, and in the seafood sector marine vessels typically need cold storage on board – which at present relies primarily on fossil fuels. In these settings, investments in sustainable cold chain solutions help farmers reduce or improve the efficiency of

[12] Least developed countries (LDCs) are low-income countries that face severe structural impediments to sustainable development. They are highly vulnerable to economic and environmental shocks and have low levels of human assets. There are currently 46 countries on the list of LDCs that is reviewed every three years by the Committee for Development Policy (CDP), a subsidiary body of the UN Economic and Social Council (ECOSOC).

[13] FAO Statistic.

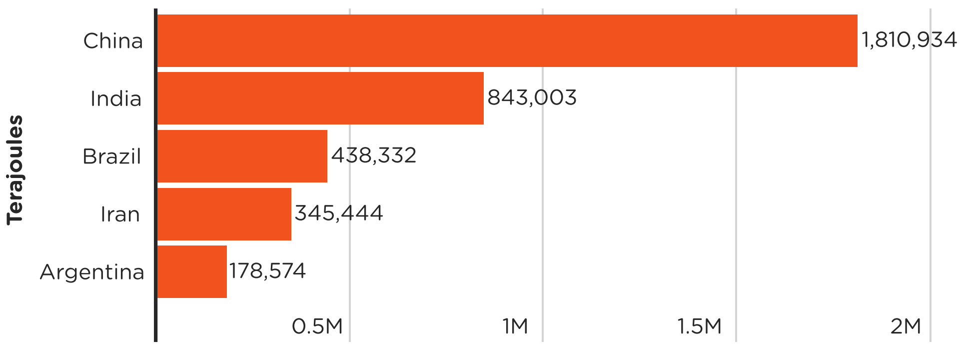
[14] Sarr, J et al. "The Carbon Footprint of the Cold Chain, 7th Informatory Note on Refrigeration and Food." IIR, 2021, Link.

their energy use while reducing food losses. At scale, these types of investments in productive uses of energy in agriculture and fisheries can reduce food loss and support reductions in energy waste that can be leveraged to expand access to unserved populations and improve the resilience of food systems.

Current energy use for food production in the 54 high-impact countries for access to cooling is dominated by major emerging economies. China's energy use for food production alone is equivalent to that of Argentina, Brazil, India and Iran combined (Figure 2.8).

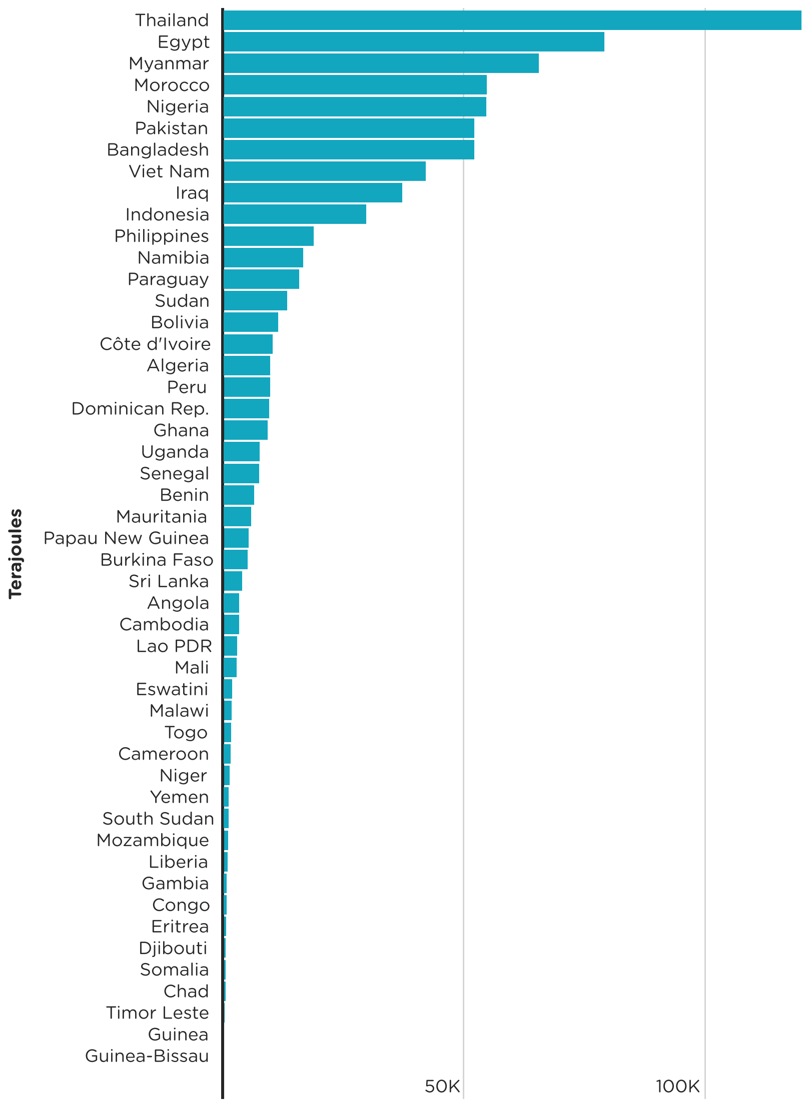
FIGURE 2.8: FOOD PRODUCTION ENERGY USE BY COUNTRY, 2019

Top five countries for energy use in food production



Source: SEforALL analysis of FAO data

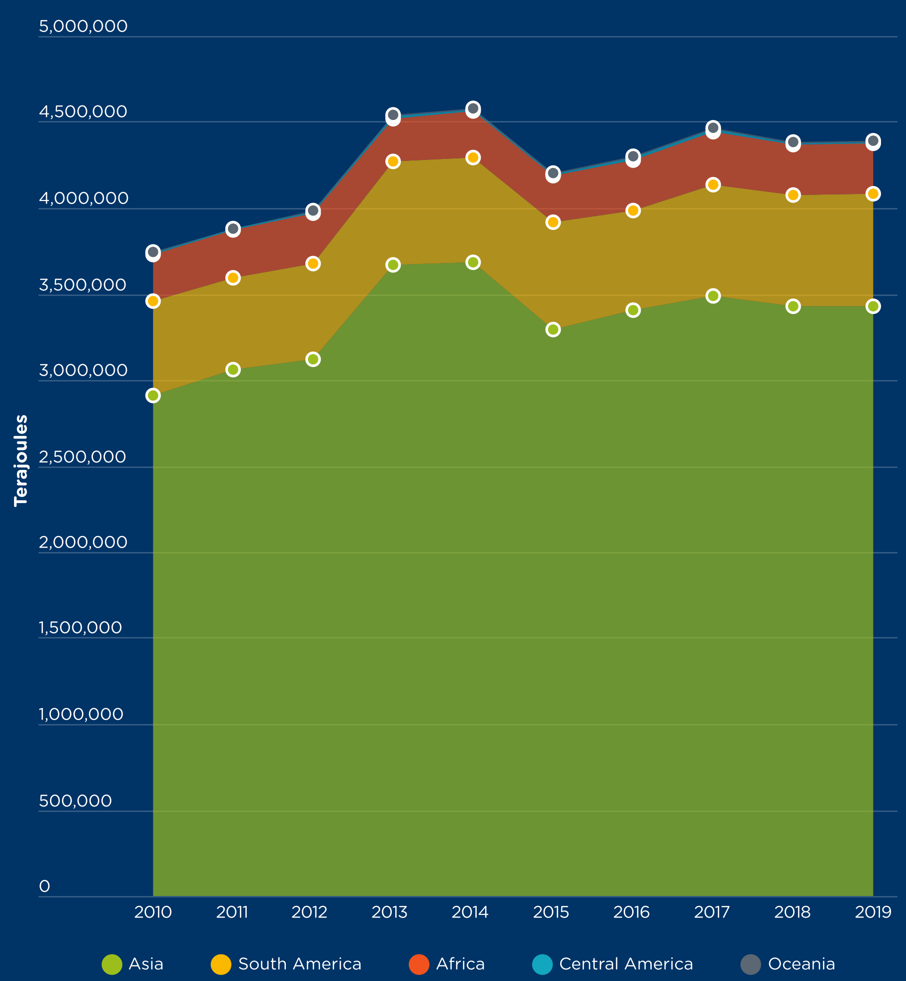
Energy use in food production among the remaining 49 high-impact countries



Source: SEforALL analysis of FAO data

Regionally, the amount of energy used in high-impact countries for access to cooling for food production, outside of manual labour, is highest in Asia, followed by South America and Africa. In Asia, 16 countries account for 78 percent of the energy use for food production, while in Africa 31 countries account for only 7 percent of energy use. It is notable that only five countries from South America account for 15 percent of energy use for food production. This trend has remained stable over the past decade (Figure 2.9).

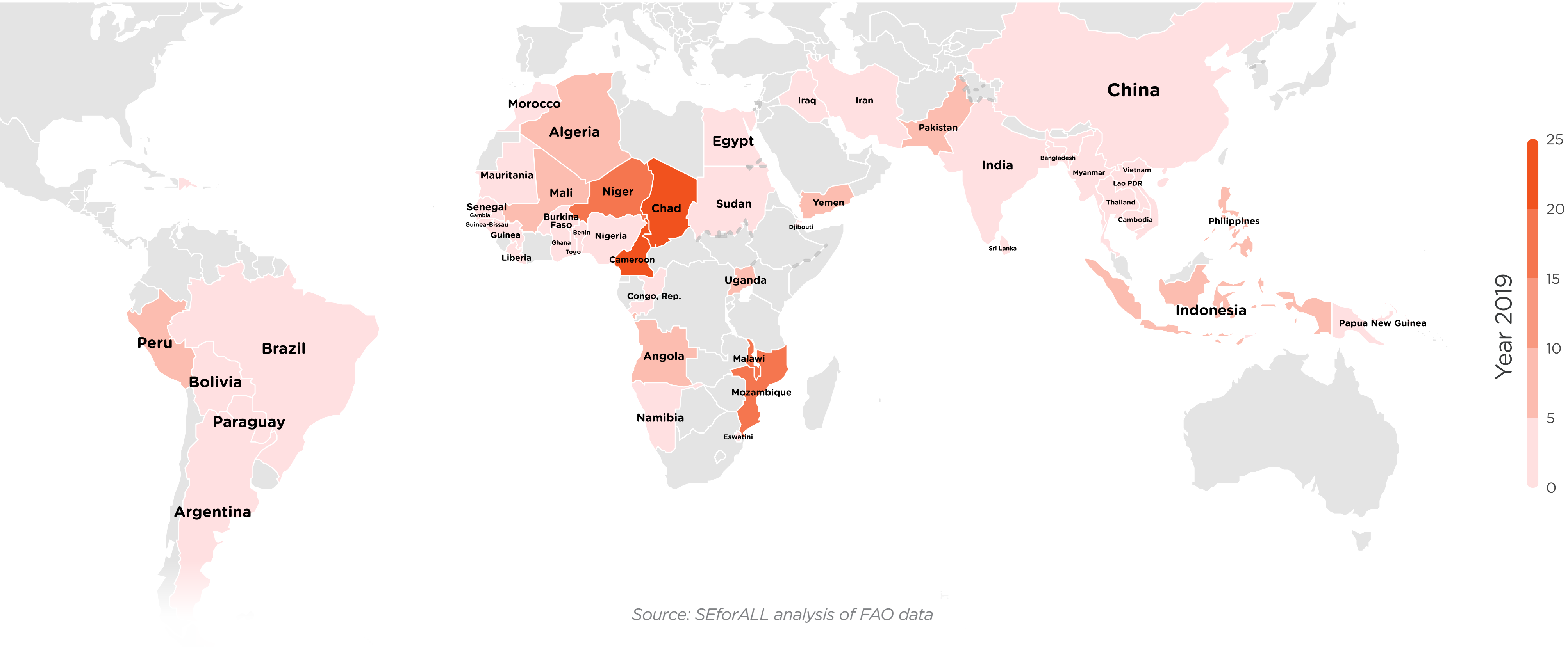
FIGURE 2.9: FOOD PRODUCTION ENERGY USE BY REGION FOR HIGH-IMPACT COUNTRIES



Source: SEforALL analysis of FAO data

The energy efficiency of food production, however, shows that even though Africa has smaller food production and energy use compared to Asia and South America, some countries in Africa are highly energy inefficient for food production. The high-impact countries have a food production energy consumption range of 0.1 to 27.4 kg of food produced per kilowatt hour (equivalent)[15] of energy used, and of the top 10 most energy-inefficient countries, eight are in Africa (Figure 2.10).

FIGURE 2.10: FOOD PRODUCTION PER UNIT OF ENERGY CONSUMPTION (KG/kWh)



Source: SEforALL analysis of FAO data

[15] Energy use in terajoules (TJ) converted to kWh of electricity for ease of reference.

Solutions for Food, Nutrition and Agriculture

The lack of sustainable, resilient, accessible and affordable cooling is a major contributing factor for food loss, impeding the development of rural economies. Solutions to these challenges are multi-faceted, but an important first step are policy and guiding frameworks that target the development of agricultural cold chains, particularly in countries in Africa and Asia with the lowest food supply. These could include specific agricultural cold chain targets and strategies within a National Cooling Action Plan (NCAP) or a long-term agricultural sectoral development plan, as well as efforts to increase the productive use of energy through an integrated energy plan.

Enabling policies for sustainable cold chains also represents a major investment opportunity of USD 270 billion in supply chain infrastructure and supply chain efficiency,[16] but must be complemented by business model strategies that allow small-scale producers to access sustainable technology. Cooling as a Service (CaaS) is a servitization model that can support this, and Community Cooling Hubs can also reduce costs by aggregating local agricultural demand for cooling.

Technological innovations in off-grid refrigeration — cooling and freezing for agricultural cold chains — have demonstrated the potential impact of new technologies but have also shown that further market development is necessary for scale. Walk-in cold rooms, for example, can reduce post-harvest losses and improve local food security, but costs are currently prohibitively high, and new business models and effective supply chains are necessary for better integration.

[16] BCG (2018). Tackling the 1.6-Billion-Ton Food Loss and Waste Crisis. Link.

2.2 Health Services

Overview

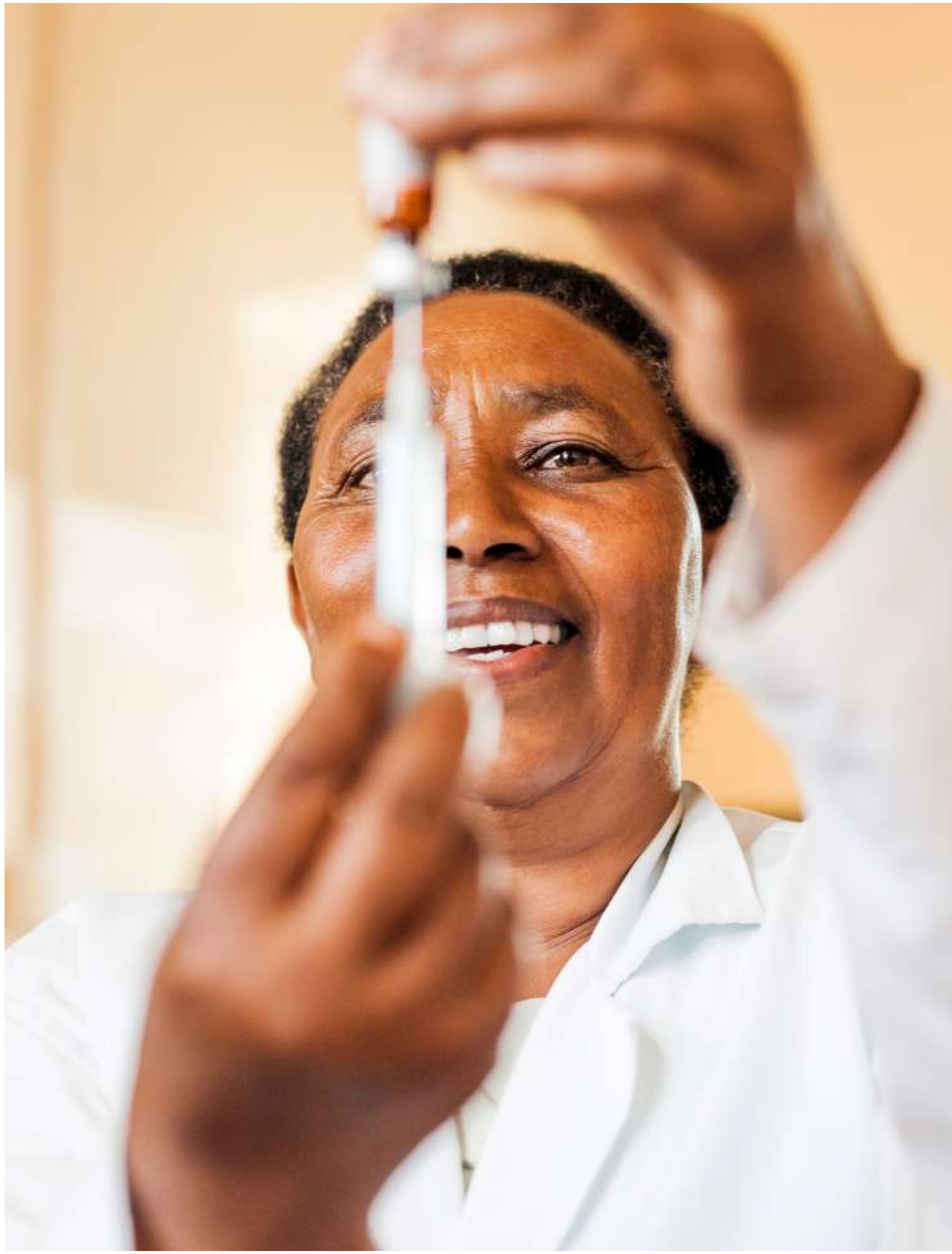
Access to sustainable cooling underpins the delivery of important components of SDG3 (good health and well-being) due primarily to the cooling needs of vaccines and blood products, as well as the need to regulate temperatures in hospitals and rural health clinics. The ability to cool hospitals, vaccines and other medical products is also typically enabled by access to electricity, highlighting the close link between SDG7 and sustainable cooling for all.

The cooling needs in health services include cold chains that transport temperature-sensitive medical products. Vaccines must typically have consistent cold storage between 2°C and 8°C to maintain their efficacy, with the exception of vaccines that require ultra-cold chain (UCC) storage of -20°C to -70°C, as was the case for the initial storage of some COVID-19 vaccines (e.g., those produced by Moderna and Pfizer-BioNTech). Blood, insulin and some medicines also require cooling, with blood, for example, stored between 2°C and 6°C, and fresh frozen plasma stored at below -30°C. Many sterilants and disinfectants must be stored below 30°C, with their effectiveness weakening when ambient temperatures are too hot. Additional cooling needs in the health sector include temperature control in hospitals and rural health centres that support better overall care and patient recovery through reductions in heat stress among patients and staff.

Vaccines

Vaccines are highly temperature sensitive. Prolonged exposure above 8°C, any exposure above 20°C, and accidental freezing can all damage or destroy vaccines. In some instances, ineffective vaccines can unknowingly be administered, leaving recipients exposed to deadly disease. Approximately 5 million children under the age of five die every year,[17] and it is estimated that 1.5 million deaths could be avoided annually through improved vaccine coverage.[18] As such, sustainable cold chains are a necessary tool in the effective delivery of immunization programmes.

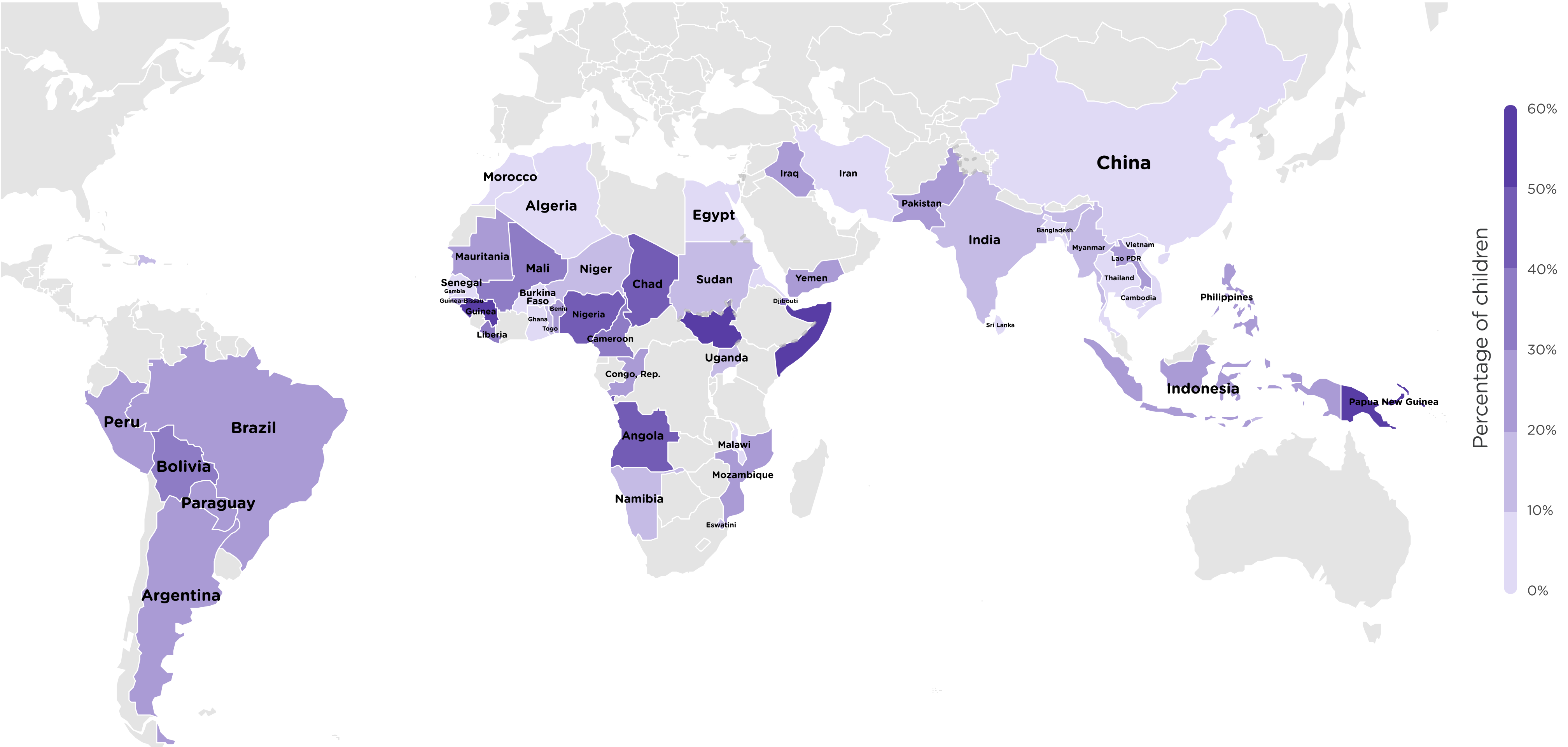
Outside COVID-19 vaccination efforts, immunization coverage rates are not keeping pace with population growth and have likely been hampered by efforts to address the COVID-19 pandemic. In 2020, the World Health Organization (WHO) reported that global coverage for the three-dose diphtheria-tetanus-pertussis vaccine (DPT3), which protects against a variety of infectious diseases, fell from 86 percent to 83 percent. This leaves 17.1 million children without an initial dose of DPT3, with an additional 5.6 million children only partially vaccinated. Among the 54 high-impact countries for access to cooling, 12 reported that more than 30 percent of children missed the third dose of the DTP vaccine between 2019 and 2020.



[17] UNICEF. Levels and trends in Child Mortality, December 2021. Link.

[18] WHO. Immunization Agenda 2030: a global strategy to leave no one behind. Geneva: WHO; 2020. Link.

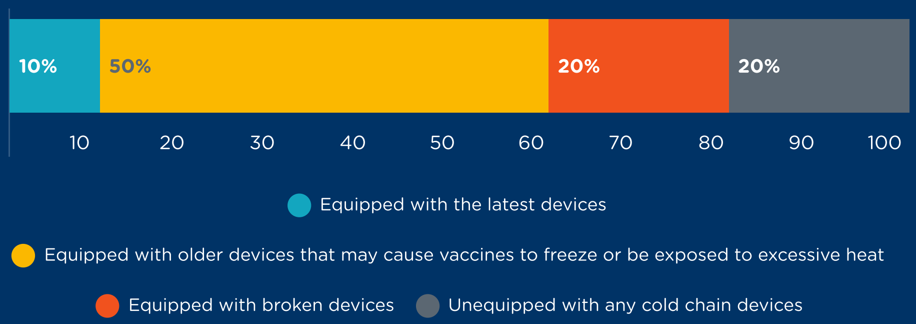
FIGURE 2.11: PERCENTAGE OF CHILDREN WHO MISSED THE THIRD DOSE OF DTP VACCINE (2019–2020)



Source: UNICEF

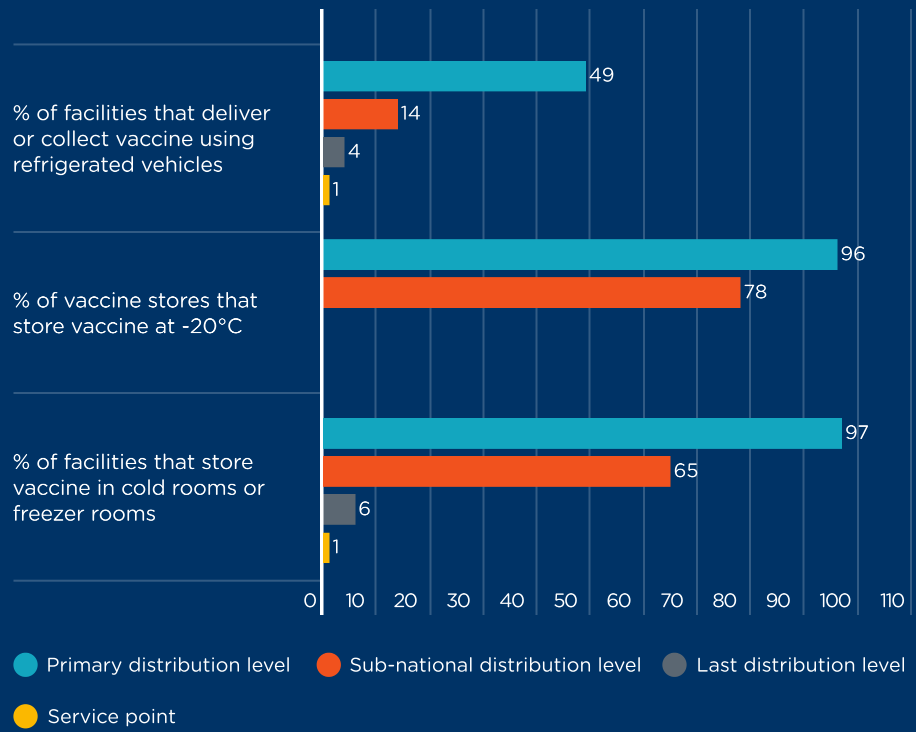
Data availability continues to be a challenge for effectively identifying vaccine cold chain gaps, however a 2014 survey among 57 Gavi-eligible countries provides a valuable baseline, finding that up to 90 percent of health facilities did not have access to reliable cold chain equipment that could guarantee vaccines were not exposed to excessive heat or excessive freezing, including 20 percent without any cold chain equipment at all (figure 2.12).[19]

FIGURE 2.12: SURVEY OF COLD CHAIN EQUIPMENT IN 57 GAVI-ELIGIBLE COUNTRIES (GAVI 2014)



WHO's Effective Vaccine Management (EVM) assessment from 2009–2020 reveals that no service points or local distribution in any of the 86 countries surveyed had storage facilities capable of maintaining temperatures of -20°C. Further, only 1 percent of service points stored vaccines in cold/freezer rooms or received vaccines from refrigerated vehicles (Figure 2.13).[20] This points to challenges with access to cooling in last-mile locations in countries covered by the assessment.

FIGURE 2.13: COLD CHAIN INDICATORS FOR 86 COUNTRIES



Source: WHO Effective Vaccine Management Assessment (2009-2020)

[19] Cold Chain Equipment Optimisation Platform, Gavi the Vaccine Alliance, December 2020. Link. Pg. 2.

[20] EVM Global Data Analysis, WHO, 2020. Link. Pg. 27.

COVID-19

The COVID-19 pandemic has increased the focus on procuring and delivering vaccine cold chain equipment. New equipment enables greater access to cooling in the short term and the cold chain infrastructure needed to support routine immunizations and other health care needs in the long term. WHO and the UN set a global COVID-19 vaccination target of 70 percent by mid-2022, noting that sufficient supply from the manufacturers was available to meet those targets, if equitable distribution was also possible.[21] With loosening supply constraints and cold chain progress, COVAX[22] now expects to reach a key milestone of over 2 billion doses[23] released for delivery. However, access inequities remain, with only 14.4 percent of people in low-income countries having received a first dose of a COVID-19 vaccine.[24]

The US Centers for Disease Control (CDC) has supported additional progress through better data by verifying that vaccines from Pfizer-BioNTech and Moderna can be stored at higher temperatures (of between 2°C and 8°C) for approximately 30 days rather than what was initially thought (-70°C and -20°C respectively) (Table 2.1). In countries with limited capacity for UCC, particularly in rural areas, these data enable medium-distance distribution, improving vaccine accessibility.

TABLE 2.1: MAXIMUM STORAGE DURATIONS AT SELECT TEMPERATURES.

Vaccine type	Manufacturer	-80 to -60°C	-25 to -15°C	2 to 8°C
mRNA	Pfizer-BioNTech	Until expiration	2 weeks	31 days
	Moderna	n/a	Until expiration	30 days
Viral vector	Johnson & Johnson	n/a	n/a	Until expiration
	Oxford-AstraZeneca	n/a	n/a	Until expiration
Inactivated	Sinopharm	n/a	n/a	Until expiration
	Sinovac	n/a	n/a	Until expiration

Source: Centers for Disease Control and Prevention (2022)

[21] Strategy to Achieve Global COVID-19 Vaccination by mid-2022, WHO, 7 October 2021. Link. Pg. 7.

[22] COVAX is a global initiative that is working with governments and manufacturers to ensure COVID-19 vaccines are available worldwide to both higher-income and lower-income countries. It is co-convened by the Coalition for Epidemic Preparedness Innovations (CEPI), Gavi, the Vaccine Alliance and WHO – working in partnership with UNICEF as a key implementing partner, developed and developing country vaccine manufacturers, the World Bank and others.

[23] UNICEF COVID-19 Vaccine Market Dashboard (data collected March 2022). Link.

[24] Hannah Ritchie, Edouard Mathieu, Lucas Rodés-Guirao, Cameron Appel, Charlie Giattino, Esteban Ortiz-Ospina, Joe Hasell, Bobbie Macdonald, Diana Beltekian and Max Roser (2020) – “Coronavirus Pandemic (COVID-19).” Link.

EFFORTS TO SCALE UP ULTRA-COLD CHAIN CAPACITY IN BANGLADESH

On behalf of COVAX, UNICEF initiated a project in 2021 to deliver more than 350 UCC freezers, some of which can store up to 336,000 vaccines, to more than 45 countries. This included Bangladesh, where through COVAX, UNICEF shipped 26 large freezers, increasing its UCC capacity by the equivalent of almost 9 million vaccines. By the end of March 2022, Bangladesh had provided the second vaccine dose to just over 107 million people, or around 63 percent of the total population, with a notable increase in vaccine uptake in March 2022. Through bilateral and multilateral agreements, donations, and the COVAX facility, the country has received 467.6 million total doses of vaccines, including 138 million (approximately 30 percent) Moderna or Pfizer-BioNTech vaccines requiring UCC. With approximately 47.3 million doses requiring UCC already administered, additional UCC capacity, and higher short-term temperature requirements for mRna vaccines, Bangladesh saw a significant increase in the administration of first, second and third doses of the Pfizer-BioNTech vaccine in early 2022.[28]

Malaria

SDG3 includes a target for ending diseases such as malaria, AIDS and tuberculosis by 2030. Yet malaria is on the rise, increasing by 14 million cases and 47,000 deaths from 2019 to 2020.[29] In Sub-Saharan Africa malaria is the primary cause of death and childhood illness, killing 260,000 African children each year.[30]

Malaria was historically treated with antiviral medications that do not require cooling, but recent vaccine developments have made cold chains an essential component of the malaria response, with the RTS,S/AS01 (RTS,S) malaria vaccine (stored between 2°C and 8°C) recommended for children in Sub-Saharan Africa.[31,32] The vaccine was trialled with 2.3 million doses in three pilot countries, where it resulted in a 30 percent reduction in deadly malaria, and saved one life for every 200 children vaccinated.[33]

In 2020, 10 countries in Sub-Saharan Africa accounted for 68 percent of malaria cases and 71 percent of deaths from malaria (Figure 2.14). With the exceptions of the Democratic Republic of the Congo and Tanzania, they are all high-impact countries for access to cooling, including Nigeria and Mozambique that are also among the Critical 9 countries.

[25] The historic push to provide ultra-cold chain freezers around the world, UNICEF, 20 September 2021. Link.

[26] COVID-19 Vaccination Dashboard for Bangladesh, Government of Bangladesh.

[27] UNICEF COVID-19 Vaccine Market Dashboard (data collected March 2022). Link.

[28] COVID-19 Vaccination Dashboard for Bangladesh, Government of Bangladesh. Link.

[29] World Malaria Report 2021. WHO, 6 December 2021. Link. Pg. vi.

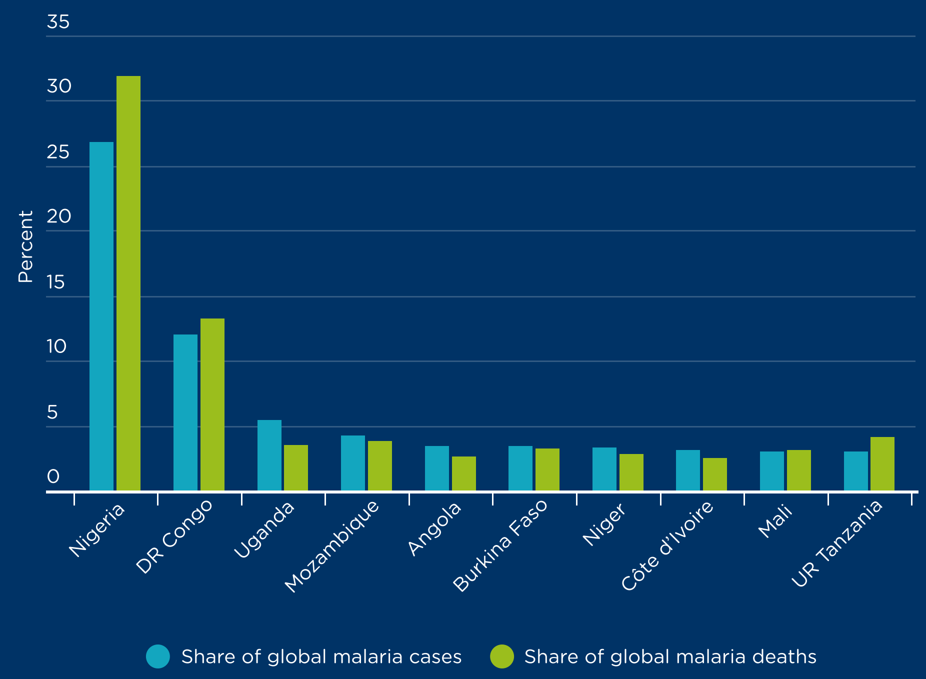
[30] WHO Recommends Ground-breaking Malaria Vaccine for Children at Risk. WHO, 6 October 2021. Link.

[31] WHO Recommends Ground-breaking Malaria Vaccine for Children at Risk. WHO, 6 October 2021. Link.

[32] Fortpied, J., Collignon, S., Moniotte, N. et al. The thermostability of the RTS,S/AS01 malaria vaccine can be increased by co-lyophilizing RTS,S and AS01. Malar J 19, 202 (2020). Link.

[33] World Malaria Report 2021. WHO, 6 December 2021. Link. Pg. 9.

FIGURE 2.14: TOP 10 COUNTRIES FOR GLOBAL MALARIA CASES AND DEATHS IN 2020



Source: WHO, 2021

Cooling in hospitals and health centres

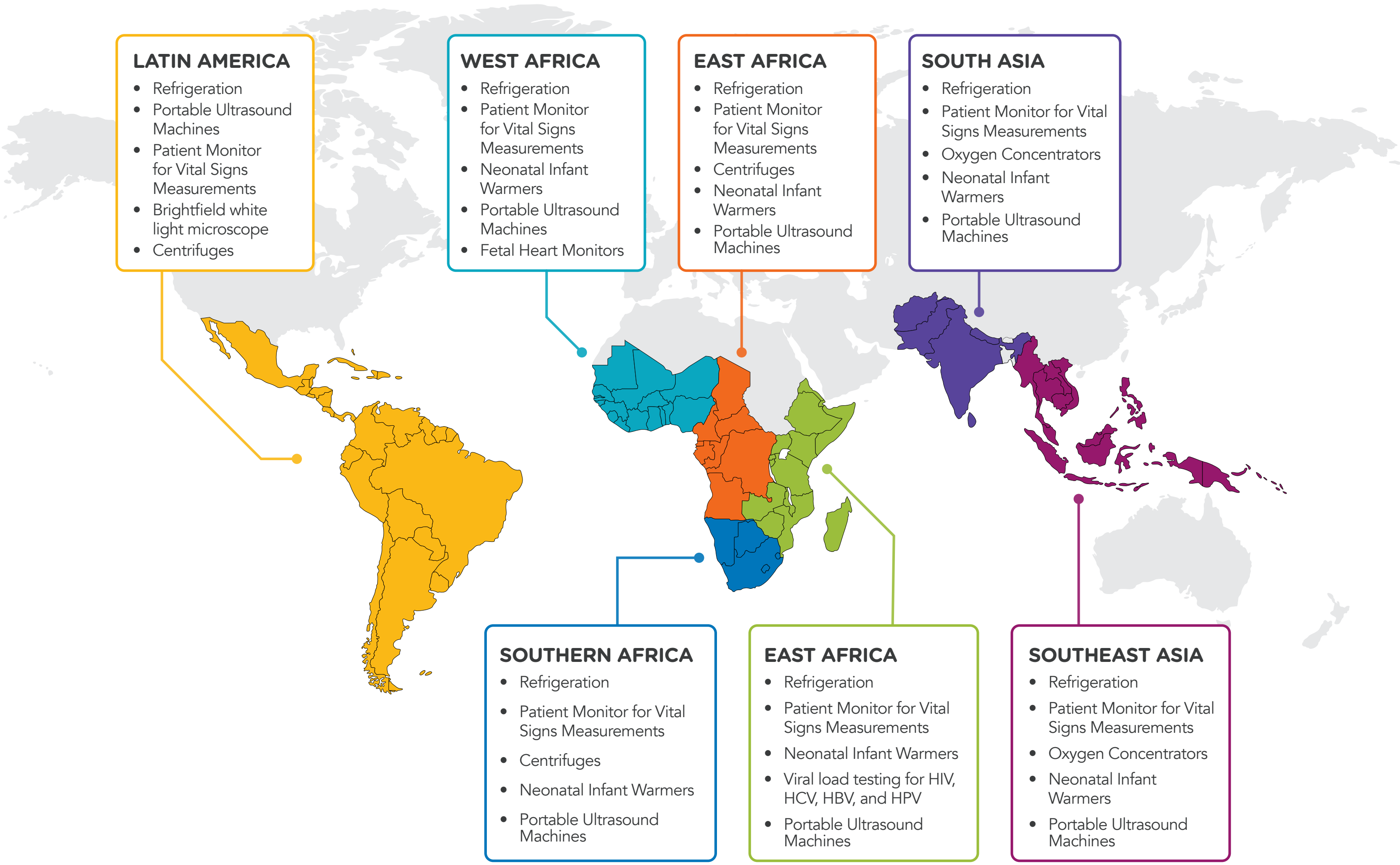
Well-functioning medical cold chains and access to refrigeration in health facilities are crucial to ensure the preservation of vaccines, blood products and medicines until they reach their target populations. In the 2018 Off-Grid Appliance Market Survey, refrigerators for vaccines and blood banks were the top items of medical equipment by perceived demand in all regions,[34] which suggests a persistent gap despite many initiatives seeking to provide off-grid clinics with refrigeration options.

Another important aspect of cooling in health centres is the presence of fans or air conditioners to reduce the adverse effects of heat on vulnerable people, especially in regions with warm and humid climates. Fans, for example, are proven effective to prevent heat-related stress and mortality in hospitals during severe heat waves, and to reduce exposure to disease-carrying insects and the spread of mould allergens.[35] Looking ahead, in a warming world, the availability of reliable space cooling and refrigeration will become increasingly vital to ensure the resilience of health services during heat extremes.

[34] Off-Grid Appliance Market Survey 2018. Efficiency for Access Coalition. Link.

[35] Fans: Solar Appliance Technology Brief, Efficiency for Access Coalition, May 2021. Link.

FIGURE 2.15: RANKING OF RELATIVE DEMAND FOR MEDICAL EQUIPMENT BY REGION[36]



[36] Off-Grid Appliance Market Survey 2018. Efficiency for Access Coalition. Link.

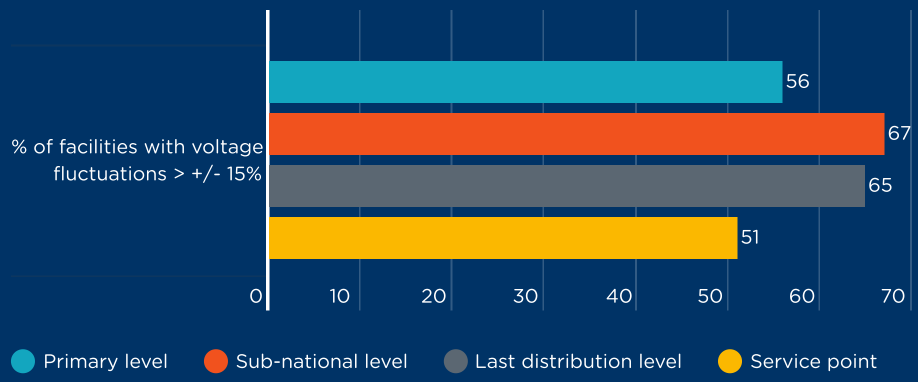
Source: Efficiency for Access

While passive cooling can reduce energy demand for cooling in health care settings, access to electricity is a necessary precondition for hospitals and health facilities to meet their cooling needs. Electricity underpins most requirements of a well-functioning health centre, from using modern equipment for medical procedures, to communication, sanitation and hygiene, lighting and facility operations as well as refrigerators, fans and air conditioners.[37]

In Gujarat, India, the state government rural electrification programme Jyotigram Yojana (JGY) introduced 24-hour electricity access to rural non-agricultural users including schools, small commercial enterprises and health centres across the state with the goal of reducing service interruptions in these settings. The programme resulted in improved cooling capacity for health facilities, with the probability of having a functioning deep freezer, ice-lined refrigerator, cold box, and vaccine carrier increasing between 5.2 and 6.6 percent.

Reliability of power supply is fundamental, yet on average, 51–67 percent of health facilities experience voltage fluctuations of at least 15 percent.[38] Cooling equipment such as ceiling fans and refrigerators for vaccines are often able to withstand moderate voltage fluctuations following power outages.[39] However, intermittent power can limit services, create facility hazards,[40] and contribute to cooling equipment breakdown.

FIGURE 2.16: VOLTAGE FLUCTUATION INDICATORS FROM THE WHO EVM ASSESSMENT



Data collected between 2009 and 2020 in 86 countries across all WHO regions. Source: WHO

Nearly 59 percent of over 121,000 health care facilities analyzed in 2018 in 46 low- and middle-income countries lack access to reliable electricity (Figure 2.16).[41] In areas with weak or no grid connection, decentralized and off-grid renewable energy can provide reliable electricity, and do so with rapidly deployable, cost-effective

[37] Impact Factsheet: Health Facility Electrification and Health Outcomes. SEforALL, 2022.

[38] Effective Vaccine Management assessment 2009–2020. WHO. Link.

[39] Franco A., Shaker M., Kalubi D., Hostettler S., A review of sustainable energy access and technologies for health care facilities in the Global South, Sustainable Energy Technologies and Assessments, Vol. 22, 2017.

[40] Cronk R, Bartram J. Environmental conditions in health care facilities in low- and middle-income countries: Coverage and inequalities, International Journal of Hygiene and Environmental Health, Vol.221, Issue 3, 2018.

[41] Cronk R, Bartram J. Environmental conditions in health care facilities in low- and middle-income countries: Coverage and inequalities, International Journal of Hygiene and Environmental Health, Vol. 221, Issue 3, 2018.

solutions.[42] In most cases, solar PV technologies can supply electricity at lower cost than diesel generators – a solution many off-grid health centres utilize.[43] Even in medium-sized off-grid health care facilities , the most appropriate energy solutions are often hybrid, combining renewable technologies with efficient batteries and back-up generators, depending on the availability and cost-effectiveness of different power solutions.[44] A recent study estimated that solar PV and battery storage would be cost-effective for 50,000 off-grid health care facilities in Sub-Saharan Africa and improve proximity of health care services for 281 million people, reducing travel time to health care facilities by 50 minutes on average.[45]

[42] Off-Grid Renewables Supply: Life-Saving Power to Rural Health Centres. IRENA, 2018. Link.

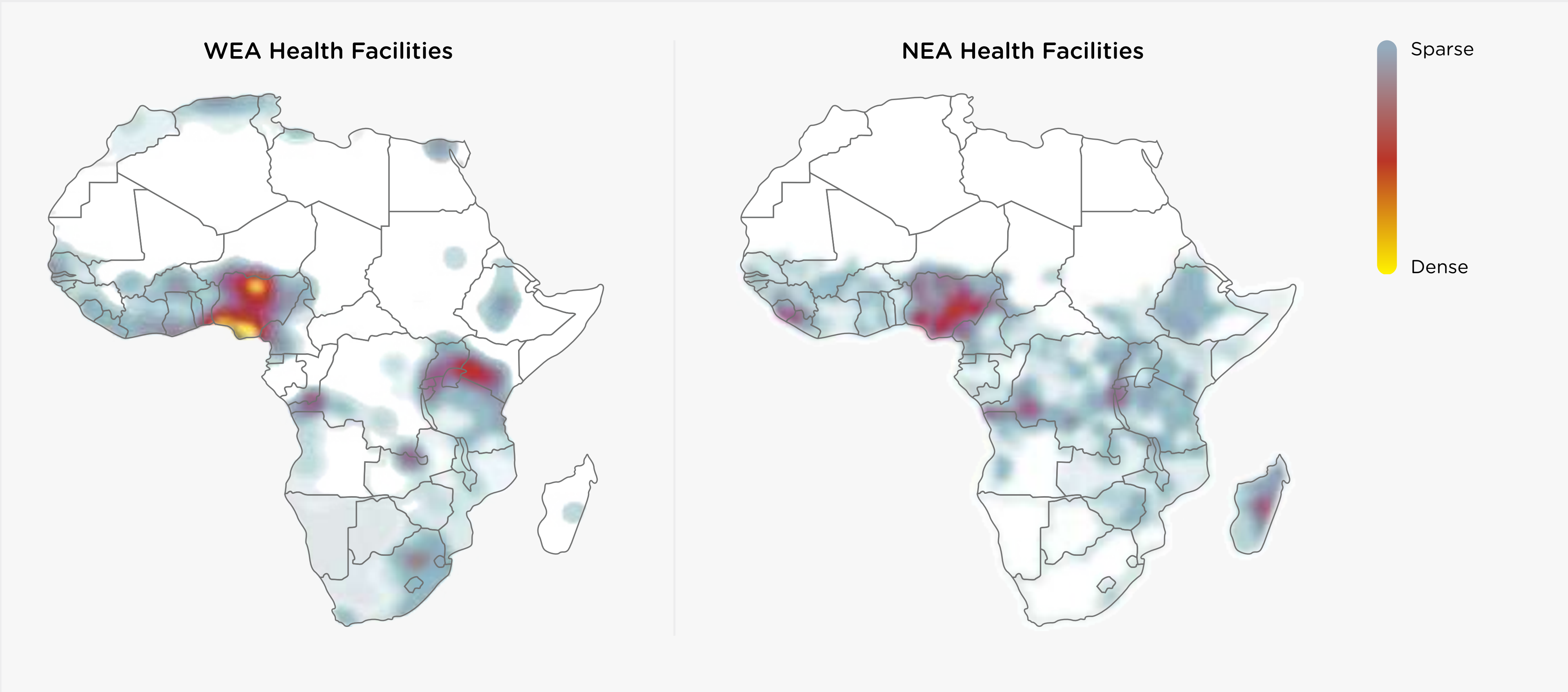
[43] Porcaro, Jem et al. “Lasting Impact: Sustainable Off-grid solar delivery models to power health and education,” UN Foundation and SEforALL, 2019. Link.

[44] Franco A., Shaker M., Kalubi D., Hostettler S., A review of sustainable energy access and technologies for health care facilities in the Global South, Sustainable Energy Technologies and Assessments, Vol. 22, 2017.

[45] Moner-Girona M., Kakoulaki G., et al. Achieving universal electrification of rural health care facilities in Sub-Saharan Africa with decentralized renewable energy technologies. Joule. Vol. 5, Issue 10, 2021.

[46] Moner-Girona M., Kakoulaki G., et al. Achieving universal electrification of rural health care facilities in Sub-Saharan Africa with decentralized renewable energy technologies. Joule. Vol. 5, Issue 10, 2021.

FIGURE 2.17: HEATMAPS OF HEALTH CARE FACILITIES WITH DETECTED ELECTRICITY ACCESS (WEA) AND NO DETECTED ELECTRICITY ACCESS (NEA)[46]



[46] Moner-Girona M., Kakoulaki G., et al. Achieving universal electrification of rural health care facilities in Sub-Saharan Africa with decentralized renewable energy technologies. Joule. Vol. 5, Issue 10, 2021.

Where power supply is constrained, energy-efficient cooling solutions allow health centres to make the most of available electricity capacity. At the same time, energy-efficient appliances can help them provide health services at lower costs.

Solutions for Health Services

Passive solutions, such as natural ventilation and shading, can help meet cooling needs and minimize energy demand in health centres. For example, the Friendship Hospital Shyamnagar, a small facility in the coastal district of Satkhira in south-western Bangladesh, was awarded as "best building in the world" in 2021 by the Royal Institute of British Architects thanks to its climate-conscious design: the hospital's buildings take advantage of wind to encourage cross-ventilation and ensure shading from direct sun while also maximizing natural light. As a result, the need for air-conditioning is limited to operating theaters and delivery rooms.[47]

Nature-based solutions, such as trees and water, can reduce temperatures in health facilities, improving care and lowering energy needs. In Singapore, the Changi General Hospital installed a garden on the roof, and together with water features and energy-efficient cooling devices and techniques, saved the facility USD 800,000 in annual energy and water costs. Without consideration of these types of solutions, health centres can become heat sinks that require resources to pay for energy that can otherwise be directed to better care.[48]

Efficient cooling appliances, such as refrigerators or air conditioners, can meet any cooling needs not met by passive or nature-based solutions. In off-grid primary health centres, refrigerators can have relatively high electric loads, and appliance efficiency can make a substantial difference. Super-efficient refrigerators require only 10 percent of the power capacity of a conventional vaccine refrigerator, allowing the same energy system to supply energy to a larger set of appliances and medical devices at the same time.[49]

In the vaccine cold chain, advances in refrigeration have helped improve reliability for the storage of vaccines in weak- or off-grid settings. Solar direct drive (SDD) refrigerators have become a more reliable option than earlier solar battery refrigerators and are more sustainable than older fridges supported by kerosene or gas.[50] Bulk public procurement of high-standard equipment by governments for the most sustainable refrigeration technologies is a key mechanism to finance these solutions in developing markets.

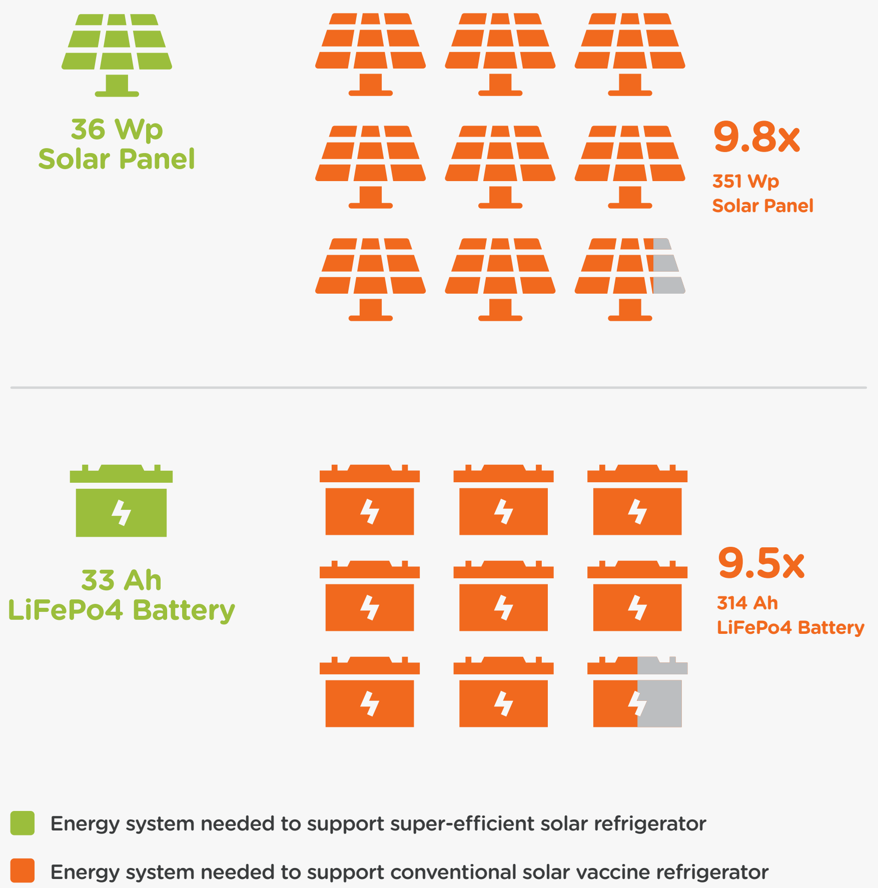
[47] Friendship Hospital Wins Riba Prize 2021. Friendship NGO. 2021. Link.

[48] Healthy Hospitals, Healthy Planet, Healthy People: Addressing Climate Change in Health Care Settings, WHO Discussion Draft. Link.

[49] Energy Efficiency and Health Access: A Preliminary Assessment, Efficiency for Access Coalition, 2018. Link.

[50] https://www.mckinsey.com/industries/public-and-social-sector/our-insights/port-to-patient-improving-country-cold-chains-for-covid-19-vaccines

FIGURE 2.18: ENERGY SYSTEM NEEDED TO SUPPORT A CONVENTIONAL OR SUPER-EFFICIENT SOLAR REFRIGERATOR



2.3 Human Comfort and Safety

Access to sustainable cooling can support achieving SDGs on health and well-being (SDG3), education (SDG4), poverty (SDG1), employment (SDG8) and sustainable cities and communities (SDG11) by delivering human comfort and safety. Cooling of cities, homes and places of employment supports improved sleep, alertness and ability to learn for students, and worker productivity that provides higher incomes for families and improved resilience for communities. In many settings, improving human comfort and safety with cooling requires access to affordable and clean electricity (SDG7).

Increasing risks to human health due to extreme heat

A warming world is increasing the risks to mental and physical health.[51] Insufficient action on climate change adaptation and the growing impacts of extreme heat on human lives underline the urgency to accelerate progress on investing in and delivering sustainable cooling for all.

In 2014, WHO released a study estimating that 12,000 people lose their lives annually due to extreme heat waves, a figure that could rise to 255,000 annually by 2050 without adaptation.[52] **New research for The Lancet has shown that the scale of the challenge is already much larger, with extreme heat causing the deaths of 356,000**

[51] It's official: July was Earth's hottest month on record. National Oceanic and Atmospheric Administration, 13 August 2021. Link.

[52] WHO (2014). Quantitative Risk Assessment of the Effects of Climate Change on Selected Causes of Death, 2030s and 2050s. Link.

people in 2019 alone.[53]

The scale of this impact, at an estimated 1.1°C of global warming, is likely to grow globally as temperatures continue to rise, posing significant risks for vulnerable groups. At between 2°C and 3°C of warming, 16 times as many people would be exposed to heat waves, rising to 36 times as many people at 4°C, causing severe risk of heat-related mortality.[54]

Vulnerable groups include newborns, children and those over the age of 65. Estimates indicate that children younger than one year and adults over 65 were exposed to 3.1 billion more per-person days of heat waves in 2020 compared to the average between 1986 and 2005.[55] In fast-growing Africa, limiting global warming to 1.8°C by 2100 will still mean that as the climate changes and the growing population ages, the number of Africans below age five and over 64 exposed to heat waves will increase from 27 million in 2010 to 360 million in 2100.[56]

Human comfort and safety for worker productivity and improved incomes

Workers face high risks from heat. The International Labour Organization (ILO) estimates that the world will suffer a worker productivity loss equivalent to 80 million full-time jobs in 2030 due to heat stress.[57] In 2018, an analysis in 30 countries found that approximately one in three individuals who are exposed to heat stress in their job experienced negative health effects.[58] In this context, labour productivity is also threatened, with the number of work hours lost due to heat increasing significantly in the last 20 years.[59] Some regions are already experiencing heat stress that affects labour productivity, and in 2020, 295 billion hours of potential work was lost. Unsurprisingly, the three Critical 9 countries in South Asia (Bangladesh, India and Pakistan) experienced losses two-and-a-half to three-times higher than the world average.[60]

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[53] Burkart, et al, Health in a World of Extreme Heat, The Lancet Vol 398, August 2021. Link.

[54] Intergovernmental Panel on Climate Change, Sixth Assessment Report: Impacts, Adaptation and Vulnerability. 28 February 2022. Link.

[55] Romanello, Marina et al, The 2021 report of The Lancet Countdown on health and climate change: code red for a healthy future. The Lancet, Vol. 398, Issue 10311. 30 October 2021. Link.

[56] Intergovernmental Panel on Climate Change, Sixth Assessment Report: Impacts, Adaptation and Vulnerability. 28 February 2022. Link.

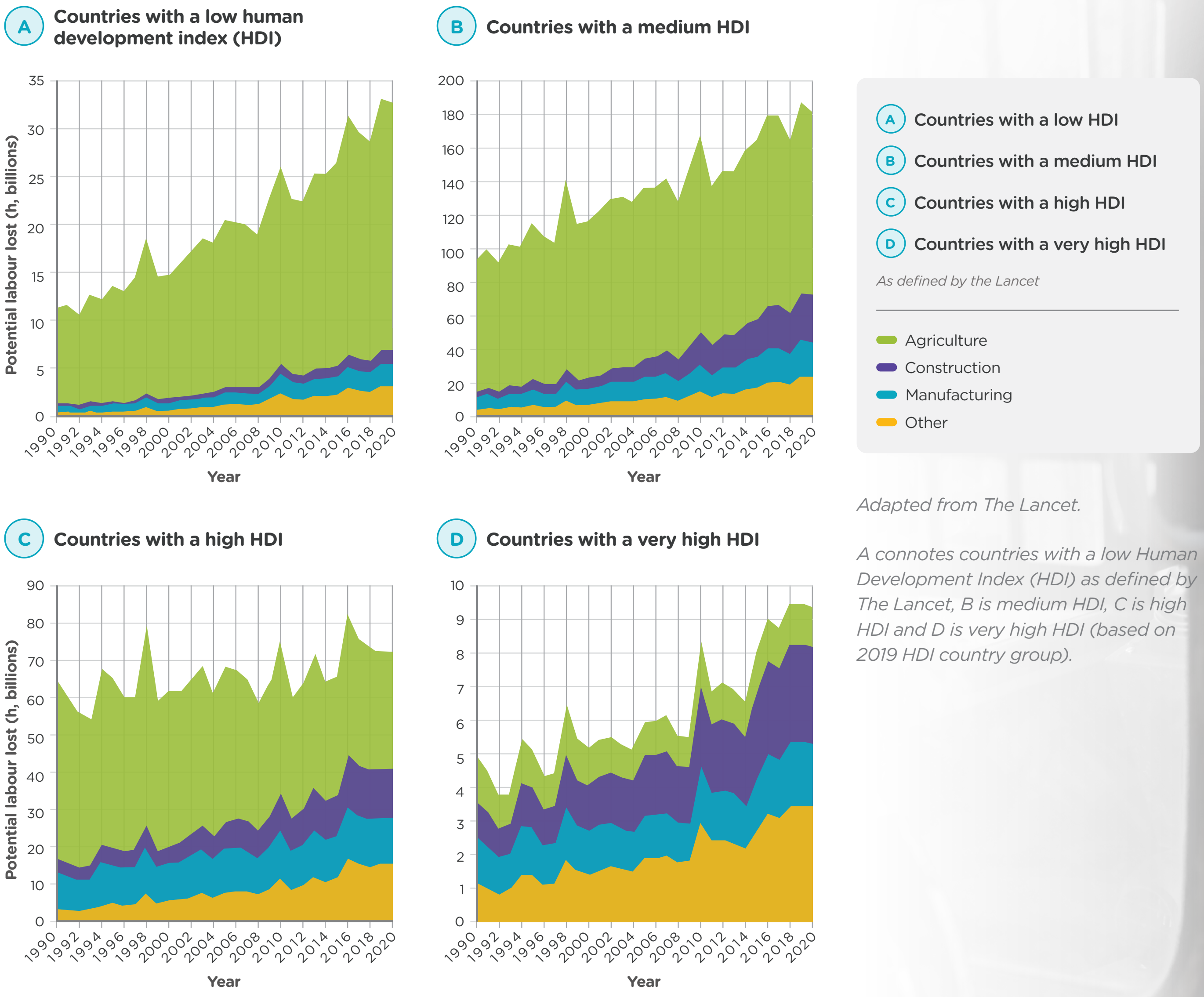
[57] Kjellstrom T, et al. Working on a warmer planet: the effect of heat stress on productivity and decent work. 2019. Link.

[58] Flouris AD, Dinas PC, Ioannou LG, et al. Workers' health and productivity under occupational heat strain: a systematic review and meta-analysis. The Lancet Planetary Health 2018; 2: e521–31. Link.

[59] Intergovernmental Panel on Climate Change, Sixth Assessment Report: Impacts, Adaptation and Vulnerability. 28 February 2022. Link.

[60] Romanello, Marina et al, The 2021 report of The Lancet Countdown on health and climate change: code red for a healthy future. The Lancet, Vol. 398, Issue 10311. 30 October 2021. Link.

FIGURE 2.19: POTENTIAL LABOUR LOST DUE TO HEAT-RELATED FACTORS IN SELECTED SECTORS (1990–2020)



Adapted from The Lancet.

A connotes countries with a low Human Development Index (HDI) as defined by The Lancet, B is medium HDI, C is high HDI and D is very high HDI (based on 2019 HDI country group).

In rural areas, extreme temperatures threaten many livestock and crops. Agricultural productivity growth in Africa has already seen a decline of 34 percent since 1961 due to climate change, more than any other region.[61] For poor rural populations, threats to agricultural livelihood assets risk triggering persistent poverty traps. For example, extreme heat waves in densely populated agricultural areas of South Asia risk increasing heat stress for farmers, while also constraining their ability to take adaptive actions.[62]

Human comfort and safety for improved learning

Children are particularly vulnerable to a lack of access to sustainable cooling, especially those living in extreme poverty and high-temperature environments. This includes the classroom, where WHO recommends a temperature of 19°C to maintain a comfortable and productive learning environment. Children respond slower during heat waves than adults, making them more likely to suffer from heat strokes and heat-related illnesses and exposure to heat extremes and high humidity rates. Low rates of access to safe drinking water are linked to fewer years of schooling.[63] Studies have shown that students score lower in high temperatures, that low-income students are disproportionately impacted, and access to cooling can mitigate most of these effects.[64] Fans and air conditioners can support better outcomes, but even passive solutions can help. In a rural area near Hyderabad, India, a passive cool roof on a school was found to reduce average classroom temperatures by 2.1°C and peak temperatures by 5°C relative to uncoated classrooms.[65]

Human comfort and safety for resilient communities and adaptation

In rapidly growing urban areas, the vulnerability of poor households is amplified by informality, exposure to air pollution and the urban heat island effect, lower quality housing, and limited access to green spaces and public services. Megacities like Buenos Aires, Rio de Janeiro and Sao Paulo alone will soon account for 22 million people exposed to growing heat stress. In South and Southeast Asia, up to 1.1 billion urban dwellers could experience heat waves lasting more than 30 days a year by 2080. In Africa, even with 1.7°C of global warming, the exposure of the urban population to extreme heat could increase more than 20 times, up to 45 billion per-person days by the 2060s, with greatest impacts in West Africa.[66]

[61] Intergovernmental Panel on Climate Change, Sixth Assessment Report: Impacts, Adaptation and Vulnerability. 28 February 2022. Link.

[62] Ibid.

[63] https://www.unicef.org/media/105376/file/UNICEF-climate-crisis-child-rights-crisis.pdf

[64] https://www.hks.harvard.edu/announcements/when-heat-student-learning-suffers and https://www.researchgate.net/publication/283837937_Effects_of_HVAC_on_student_performance

[65] https://www.researchgate.net/publication/282620876_Assessment_of_the_Impact_of_Cool_Roofs_in_Rural_Buildings_in_India

[66] Intergovernmental Panel on Climate Change, Sixth Assessment Report: Impacts, Adaptation and Vulnerability. 28 February 2022. Link.

Cooling solutions for human comfort and safety

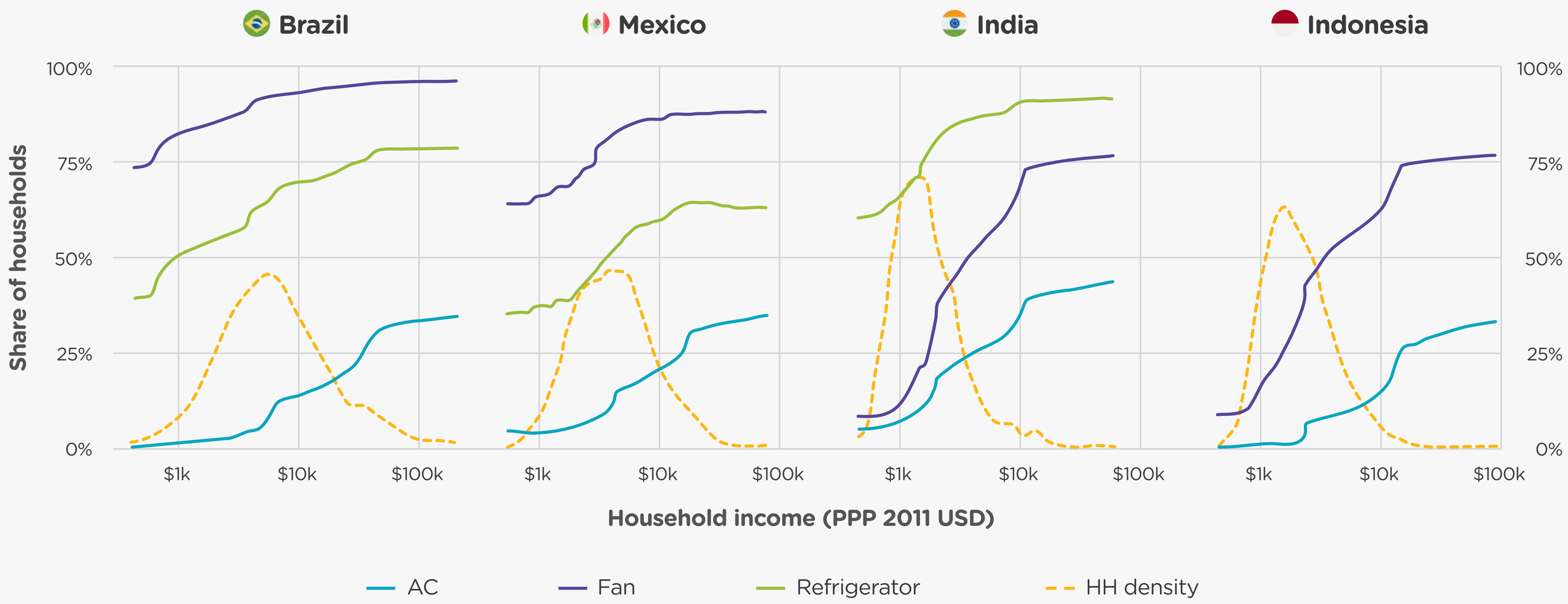
Human tolerance to heat has physiological limits. Higher average and extreme temperatures will cause these limits to be reached more regularly in the coming decades, especially in tropical regions.[67] Access to adequate cooling solutions will be fundamental, and demand for air-conditioning is expected to soar, driven by growing income levels and the need to adapt to global warming.[68] However, faster diffusion of inefficient units could lead to unintended consequences that include higher emissions, higher peak electricity demand, brown or blackouts, a more pronounced urban heat island effect, and heat inequities for those not able to afford air-conditioning.

As household incomes increase in developing countries, trends show that air conditioner, fan and refrigerator ownership also increases (Figure 2.20). In India, refrigerator ownership among low-income households is much higher than that of either fans or air conditioners, while fan ownership is much higher in both Brazil and Mexico.

[67] Intergovernmental Panel on Climate Change, Sixth Assessment Report: Impacts, Adaptation and Vulnerability. 28 February 2022. Link.

[68] Ebi K. L. et al., 2021, P698-708, 21 August 2021. Link.

FIGURE 2.20: COOLING TECHNOLOGY USE BY HOUSEHOLD INCOME (PPP 2011 USD)[69]



[69] Pavanello, F., De Cian, E., Davide, M. et al. Air-conditioning and the adaptation cooling deficit in emerging economies. Nat Commun 12, 6460 (2021). Link.

The availability and affordability of sustainable cooling solutions underpin how most vulnerable populations can achieve comfort and safety. Strategies to reduce heat-related risks and improve thermal comfort can include a range of cooling solutions (see *Chilling Prospects 2020*, Chapter 4) including passive cooling, nature-based solutions, energy-efficient and climate-friendly air-conditioning, and heat-stress planning policies.

Passive cooling is an effective first-order cooling solution that can provide thermal comfort independently depending on heat tolerance and contribute to reduced energy demand for cooling in high temperature environments where mechanical cooling is necessary, as well as provide respite from extremely high temperatures. In urban poor settings where informal households do not have access to quality electricity and cannot afford active cooling solutions, the use of cool roofs has proven to be a cost-effective solution that can improve resilience among this vulnerable population.

Nature-based cooling includes trees, vegetation, urban greening, water storage and moving water that can reduce temperatures, help offset the urban heat island effect, and improve air quality. Nature-based solutions can be installed either at the property or through urban planning designed and invested in at the community scale. Despite the benefits, cities currently invest less than 0.3 percent of their infrastructure budgets on nature-based solutions.[70]

THE FIRST CHIEF HEAT HEALTH OFFICERS

Personnel can be a part of policy, as demonstrated by the creation of the First Chief Heat Health Officers in 2021. In partnership with the Adrienne Arsht-Rockefeller Foundation Resilience Center, the cities of Athens, Greece; Freetown, Sierra Leone; Santiago, Chile; and Miami Dade County in the US have appointed the world's first Chief Heat Officers to raise awareness of heat risks and lead planning efforts to respond to heat waves. The positions are designed to ensure each city has a person responsible for heat health and the protection of vulnerable residents by providing access to cooling. To learn more, see our Partner Story from the Resilience Center.

Active (mechanical) solutions are generally effective in managing thermal discomfort in high temperature and humid locations.[71] Here, access to reliable electricity is an important factor to make active cooling solutions available. Affordability also drives the type of solution that would be utilized since capital and operating costs can be significant, particularly in poor settings. Owning a ceiling or a table fan is typically the first active space-cooling solution accessed by poor populations that have only tier 1 electricity access. But with higher quality electricity access and greater affordability among lower-

[70] BiodiverCities by 2030: Transforming Cities' RelationShip with Nature, World Economic Forum, January 2022. Link.

[71] Ollie J. et al., Reducing the health effects of hot weather and heat extremes: from personal cooling strategies to green cities. P709-724, August 21, 2021. Link.

middle income and middle-income populations, ownership rates increase for more advanced solutions such as evaporative coolers and air conditioners. Air-conditioning is proven to strongly protect against the adverse health effects of extreme heat, to reduce thermal discomfort, and to improve indoor workplace productivity.[72]

According to CLASP, it is estimated that total global ownership of space-cooling solutions such as ceiling fans will reach about 2.5 billion units in 2030, with the number of air conditioners increasing to around 1.5 billion units.[73] The energy demand from these appliances is expected to reach about 2,500 TWh, with 98 percent of this demand from air conditioners.[74] Improving the efficiency of portable fans should be considered as important as fixed appliances, as they can be the first tier 1 active cooling solutions that vulnerable groups access and rely on in conditions of unreliable electricity supply and energy poverty. Policy support for cost-effective energy-efficient ceiling fans would not only improve energy poverty conditions but also extend energy access by reducing waste energy.

THE ROLE OF MINIMUM ENERGY PERFORMANCE STANDARDS

Minimum energy performance standards (MEPS) and high energy performance standards (HEPS) are policy measures that can support improving the energy efficiency of air conditioners to minimize energy demand, improve affordability, and lower emissions. The UN Environment Programme (UNEP) United for Efficiency (U4E) initiative, for example, estimates that electricity for air-conditioning accounts for up to 60 percent of summer loads in metropolitan areas in hot climates, and that the most efficient air conditioners are 30 percent more efficient than the average products on the market.[75] To this end, it has published a model regulation for air conditioners and has supported a number of countries, including Nigeria and Sudan, in implementing higher performance standards for air conditioners.

[72] Ollie J. et al., Reducing the health effects of hot weather and heat extremes: from personal cooling strategies to green cities. P709-724, August 21, 2021. Link.

[73] CLASP: Mepsy: The Appliance & Equipment Climate Impact Calculator. Link.

[74] CLASP: Mepsy: The Appliance & Equipment Climate Impact Calculator. Link.

[75] United for Efficiency, Approach to Air Conditioners. Link.

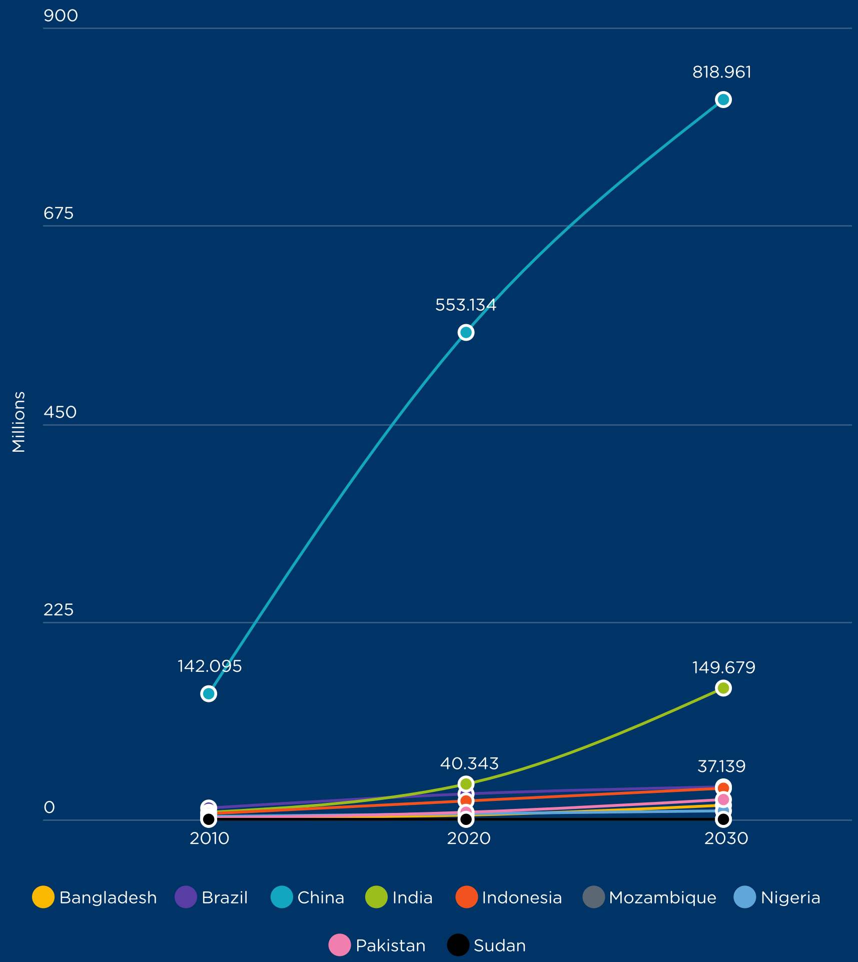
Air conditioners use refrigerants such as HCFCs (hydrochlorofluorocarbons) and HFCs (hydrofluorocarbons) that are short-lived climate pollutants and substances with high Global Warming Potential (GWP) currently controlled through the Montreal Protocol. It has been estimated that by promoting energy-efficient air conditioners and refrigerators along with climate-friendly refrigerants, around 0.4°C of global average temperatures could be avoided by the turn of the century.[76]

In the Critical 9 countries, ownership of active cooling solutions is increasing as both population and income levels grow (Figures X, X, X) and as electrification rates improve, ownership of such appliances is expected to increase further. The International Energy Agency (IEA) estimates that energy demand for space cooling will reach 30 percent of the total final energy consumption by 2050.[77]

[76] Dreyfus et al. IGSD 2019.

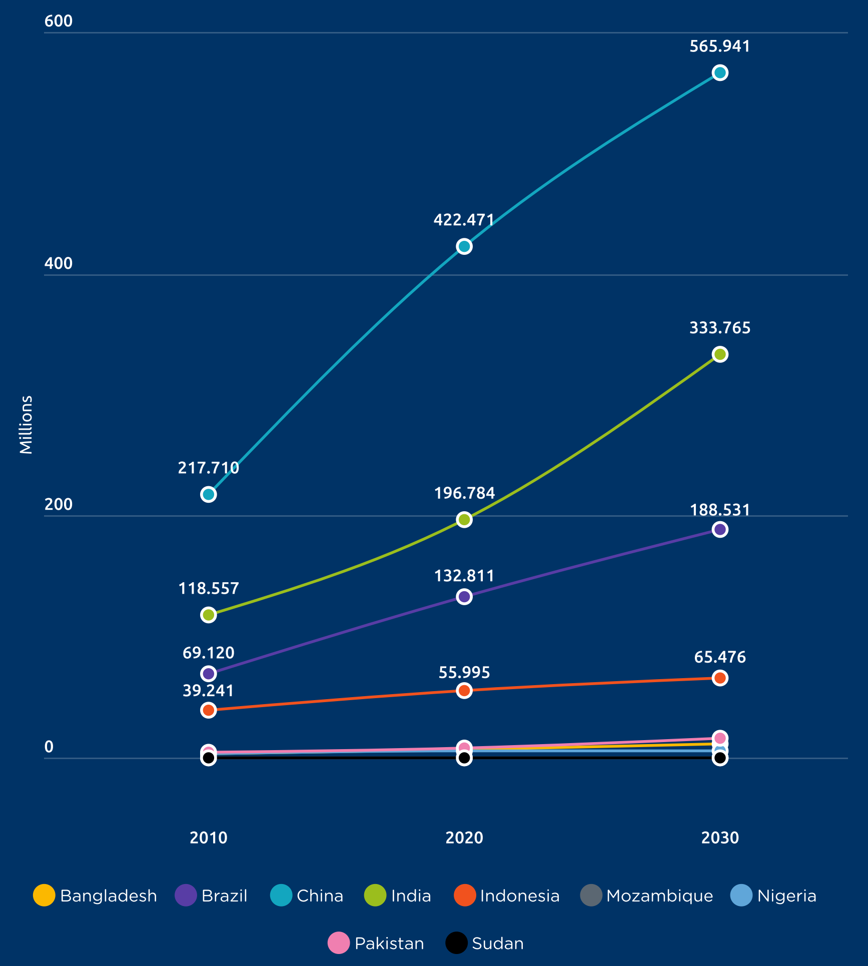
[77] IEA, Future of Cooling, 2018.

FIGURE 2.21: AIR CONDITIONER APPLIANCE TRENDS IN THE CRITICAL 9 COUNTRIES



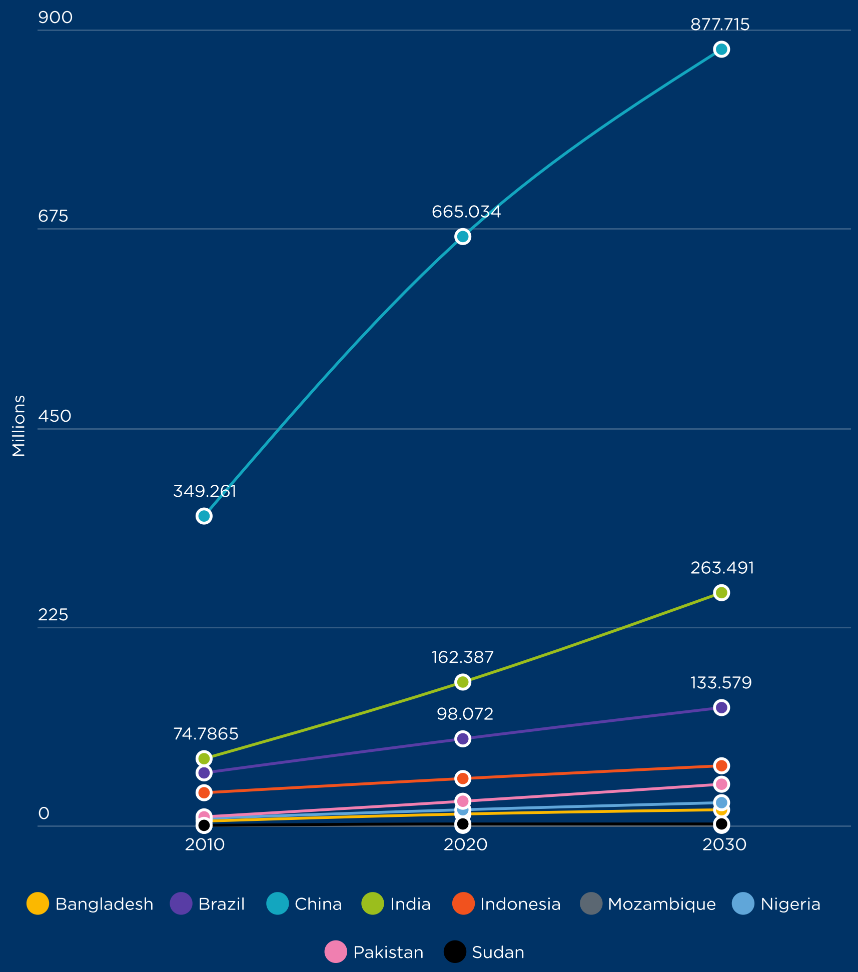
Source: 'Mepsy: The Appliance & Equipment Climate Impact Calculator', CLASP, V1.2, February 2022, https://clasp.shinyapps.io/mepsy. (2022)

FIGURE 2.22: CEILING AND PORTABLE FAN APPLIANCE TRENDS IN THE CRITICAL 9 COUNTRIES



Source: 'Mepsy: The Appliance & Equipment Climate Impact Calculator', CLASP, V1.2, February 2022, https://clasp.shinyapps.io/mepsy. (2022)

FIGURE 2.23: REFRIGERATOR AND FREEZER APPLIANCE TRENDS IN THE CRITICAL 9 COUNTRIES



Source: 'Mepsy: The Appliance & Equipment Climate Impact Calculator', CLASP, V1.2, February 2022, https://clasp.shinyapps.io/mepsy. (2022)

2.4 Sustainable Cooling for Cities

Due to various factors, cities all over the world have high temperatures that reduce the quality of life for the residents who call the cities home and the workers who spend the day in them. Understanding access to sustainable cooling gaps and urban heat exposure through better data and analysis can support improved policymaking and investment decision-making that mitigates high temperatures and improves access to sustainable cooling.

Urban heat exposure and urbanization

Urban heat is driven by climate conditions, the topography of the land, the urban built environment, and waste heat, among other factors. The features of the urban environment are known to cause a higher temperature than their rural, or less developed, surroundings, typically referred to as the urban heat island.[78] The urban heat island effect (UHIE) can cause city temperatures to be 1°C to 4°C higher on average — often most pronounced overnight — with maximum temperature differentials of up to 10°C being observed. Exposure to extreme heat in urban settings has increased by almost 200 percent since the mid-1980s and is estimated to affect 1.7 billion people.[79] UHIEs have proven to increase energy use, greenhouse gas (GHG) emissions, and waste heat from mechanical cooling, which in turn both creates and exacerbates urban heat, smog and air pollution.[80]

These urban heat conditions mean that urban populations can be at higher risk of heat exposure, with the poor and elderly being disproportionately affected.[81] Those who work outdoors, such as in marketplaces, in construction, or in under-ventilated spaces are also at risk from urban heat exposure.[82]

The challenge for many cities globally is that urban populations are growing rapidly. It is expected that 90 percent of urbanization in the next four decades will occur in Asia and Africa,[83] which currently face both extreme heat and limited access to sustainable cooling.[84] Even without the expected urbanization, cities already account for over 75 percent of global emissions on just 1 percent of the earth's ice-free land surface[85] and replicating business-as-usual urbanization threatens the long-term sustainability of energy systems, the climate

78 Oke, T. R. (1973). City size and the urban heat island. Atmospheric Environment, 7(8), 769–779. https://doi.org/10.1016/0004-6981(73)90140-6

79 Cascade, T., Kelly, C., Chris, F., Andrew, V., Stuart, S., Kathryn, G., Pete, P., & Tom, E. (2021). Global urban population exposure to extreme heat. Proceedings of the National Academy of Sciences, 118(41), e2024792118. https://doi.org/10.1073/pnas.2024792118

80 Mi Aye Su, Jack Ngarambe, Mat Santamouris, Geun Young Yun, Empirical evidence on the impact of urban overheating on building cooling and heating energy consumption, iScience, Volume 24, Issue 5, 2021.

81 Heaviside, C., Macintyre, H., & Vardoulakis, S. (2017). The Urban Heat Island: Implications for Health in a Changing Environment. Current Environmental Health Reports, 4(3), 296–305. https://doi.org/10.1007/s40572-017-0150-3

82 Ebi, K. L., Capon, A., Berry, P., Broderick, C., de Dear, R., Havenith, G., Honda, Y., Kovats, R. S., Ma, W., Malik, A., Morris, N. B., Nybo, L., Seneviratne, S. I., Vanos, J., & Jay, O. (2021). Hot weather and heat extremes: health risks. The Lancet, 398(10301), 698–708. https://doi.org/10.1016/S0140-6736(21)01208-3

83 Cascade, T., Kelly, C., Chris, F., Andrew, V., Stuart, S., Kathryn, G., Pete, P., & Tom, E. (2021). Global urban population exposure to extreme heat. Proceedings of the National Academy of Sciences, 118(41), e2024792118. https://doi.org/10.1073/pnas.2024792118

84 SEforALL. (2020) Chilling Prospects.

85 BiodiverCities by 2030: Transforming Cities' Relationship with Nature, World Economic Forum, January 2022. Link.

and human lives.

The Intergovernmental Panel on Climate Change (IPCC) has highlighted the risks posed to cities from increasing temperatures without adaptation to climate change.[86] By 2080, in South and Southeast Asia alone, between 940 million and 1.1 billion urban dwellers could experience extreme heat that lasts more than 30 days a year.

Factors for urban heat exposure or effect

The relationships between people, place and environment provide a way of understanding which features are important to include when measuring and assessing heat exposure conditions. The impact of heat exposure for individuals depends on factors such as the nature and duration of heat exposure, their underlying health conditions, and their ability to adapt their conditions to mitigate or minimize exposure (e.g., reducing direct exposure to outdoor work, or affording and using air-conditioning).

Heat exposure itself depends on conditions in urban areas of: (1) location characteristics, such as climate, weather conditions (including temperature, humidity and wind speed), topography, movement of air, and the amount and type of natural surroundings of the city; (2) physical infrastructure, such as building and material choices for city design, access to electricity, availability of water- and nature-based infrastructure such as street tree canopies and vegetated/forested areas; and (3) social infrastructure, such as health services and cooling alert systems.

Elevated ambient heat conditions are the product of changes in the urban and surrounding landscape that affect local climate conditions when compared to historic trends. Climate change is also a key driver of changes in ambient heat conditions and plays a major role in increasing urban heat conditions quickly compared to urban population growth. When investigating changes in ambient heat conditions, longitudinal data and long-term changes in land use, infrastructure and demographics are very important to understanding heat risks.

Measuring urban heat

Common measurements of heat exposure focus on two types of conditions, chronic ambient conditions (i.e., climate) and acute or extreme conditions (i.e., heat waves).

There are a range of commonly used temperature and environmental indicators to measure urban heat conditions, each of which describes different aspects of heat conditions experienced (see Box 1). When evaluating urban-heat conditions, these temperature-related measurements are used alongside other urban-feature indicators that are linked to heightened heat exposure risk, such as: land-use change, population growth and structure, energy access and affordability, and socioeconomic data.

[86] Intergovernmental Panel on Climate Change, Sixth Assessment Report: Impacts, Adaptation and Vulnerability. February 28, 2022. Link.

BOX 1: URBAN HEAT MEASUREMENT INDICATORS

Land Surface Temperature (LST): The measure of how warm or cold the earth surface is to touch in any given location. Typically measured through satellite, the LST correlates to air temperature.

Daily mean temperature (DMT): The mean of the temperatures observed over a continuous 24-hour period.

Days with T_{max} >X°C: The number of days with a maximum temperature (Tmax) above threshold temperatures (e.g., 25°C or 30°C).

Excess heat factor:[87] When the three-day-average DMT compared to the annual temperature threshold at a particular location is higher than the 95th percentile of DMT for a three-day-period, it is defined as a heat wave. The three-day period is then compared to the past 30 days to determine intensity.

Monthly maximum value of daily maximum temperature (T_x): The daily maximum temperatures in a given month for a given period.

Daily temperature range (DTR): The monthly mean difference between the monthly maximum value of daily maximum temperature (TX) and the monthly maximum value of daily minimum temperature.

Wet bulb globe temperature (WBGT): A measure of the heat stress in direct sunlight that takes into account temperature, humidity, wind speed, sun angle and cloud cover. The WBGT provides a measure for assessing the risk of heat conditions and outdoor activities (work or exercise).

Heat index / apparent temperature:[88] The temperature as it feels to the human body when relative humidity and air temperatures are combined. The measure provides a way of accounting for how air conditions remove sweat from the human body through evaporation. An air temperature of 30°C and relative humidity of 60 percent will have a feels like temperature of 33°C and indicates an extreme caution heat index.

[87] Nairn, J., & Fawcett, R. (2014). The Excess Heat Factor: A Metric for Heatwave Intensity and Its Use in Classifying Heatwave Severity. International Journal of Environmental Research and Public Health, 12(1), 227–253. MDPI AG. Retrieved from http://dx.doi.org/10.3390/ijerph120100227

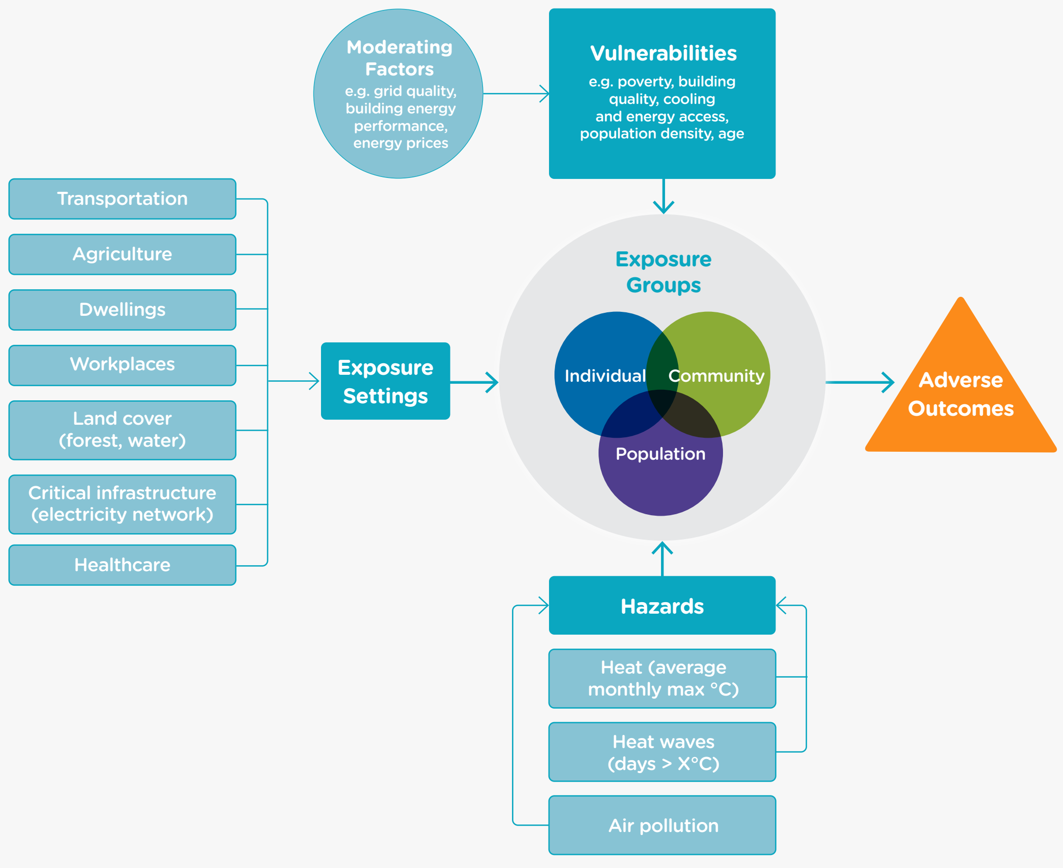
[88] NOAA. (2022). What is the heat index? National Oceanic and Atmospheric Administration. https://www.weather.gov/ama/heatindex

In addition to heat measurements, there are numerous drivers and factors that affect an individual's or a population's exposure to heat. A useful framework for understanding the impacts of urban heat exposure is through risk assessment, which defines hazards, vulnerabilities and exposures, and can be applied to urban geographies to evaluate heat risk.[89]

Together, these non-exhaustive parameters define the incremental heat exposure for a given place and contribute to the risk of being exposed to excessive heat levels that place a burden on people, government and businesses.

A risk assessment framework applied to urban heat exposure works to identify the set of factors that act to influence the risk for people, place and environment to being exposed to heat that would be considered excess or potentially unsafe (see Figure 2.24). It uses hazard features, such as the level and frequency of heat experienced, and modifiers, such as air pollution. It accounts for the point of exposure, i.e., workplaces, housing and public spaces, and features of vulnerability, such as population density, poverty levels and access to electricity or cooling. It also considers the climate and topographic features that further act to modify heat exposure, such as green space or mountain features.

FIGURE 2.24: URBAN HEAT EXPOSURE RISK ASSESSMENT FRAMEWORK, SEFORALL



[89] Tomlinson, C.J., Chapman, L., Thornes, J.E. et al. Including the urban heat island in spatial heat health risk assessment strategies: a case study for Birmingham, UK. Int J Health Geogr 10, 42 (2011). https://doi.org/10.1186/1476-072X-10-42

A heat exposure toolkit for cities

As cities focus on addressing the implications of a changing climate and future population growth and the associated infrastructure and social services, alongside the form and function of the city, there is a need for toolkit approaches that provide an understanding of the risks being faced and their drivers, as well as strategies that aim to both mitigate and adapt to heat.

The *This is Cool* Solutions Assessment toolkit provides guidance for city policymakers interested in knowing what policies are available to mitigate and address heat and lack of cooling services within their cities. Additional resources include the Cool Coalition's *Beating the Heat: A Sustainable Cooling Handbook for Cities*, as well as primers from the World Bank Energy Sector Management Assistance Program (ESMAP) unit on Reducing Excessive Urban Heat.

In focusing on where to apply policies that act to reduce heat exposure and vulnerabilities, city officials can put in place strategies that both reduce urban heat conditions and invest in measures that help cities to adapt to increasing heat conditions. City officials can also look to increasing resilience and reducing vulnerabilities for people through social services, such as cooling centres, heat wave warning systems, and supporting people during heat waves.

Policymakers in cities face considerable challenges in how to manage drivers affecting current and future heat conditions but can use an integrated urban heat exposure risk assessment tool to evaluate risks and identify measures that can move cities towards safe heat conditions and sustainable cooling solutions.

Analysis of urban heat implications from land-use change

The following analysis examines the impact of land-use change since 2015 in major cities in each of the Critical 9 countries and examines the implications of urbanization for urban heat. The annual global land-cover change maps[90] from the Copernicus Land Monitoring Service[91] form the basis of this analysis and the year-over-year land-use change was measured using QGIS[92] and Rstudio.[93]

The analysis uses mean projections for each city using IPCC's most optimistic emissions scenario –[94] the Shared Socioeconomic Pathway (SSP1-1.9 scenario) from the Climate Change Knowledge Portal,[95] where the global CO_2 emissions are cut to net zero around 2050. This is the only scenario that meets the Paris Agreement's goal of keeping global warming to 1.5°C above preindustrial temperatures.

[90] Global Land Cover, Copernicus. Land Cover Viewer (vito.be)

[91] Buchhorn, M. ; Lesiv, M. ; Tsendbazar, N. - E. ; Herold, M. ; Bertels, L. ; Smets, B. Copernicus Global Land Cover Layers — Collection 2. Remote Sensing 2020, 12, Volume 108, 1044. DOI 10.3390/rs12061044

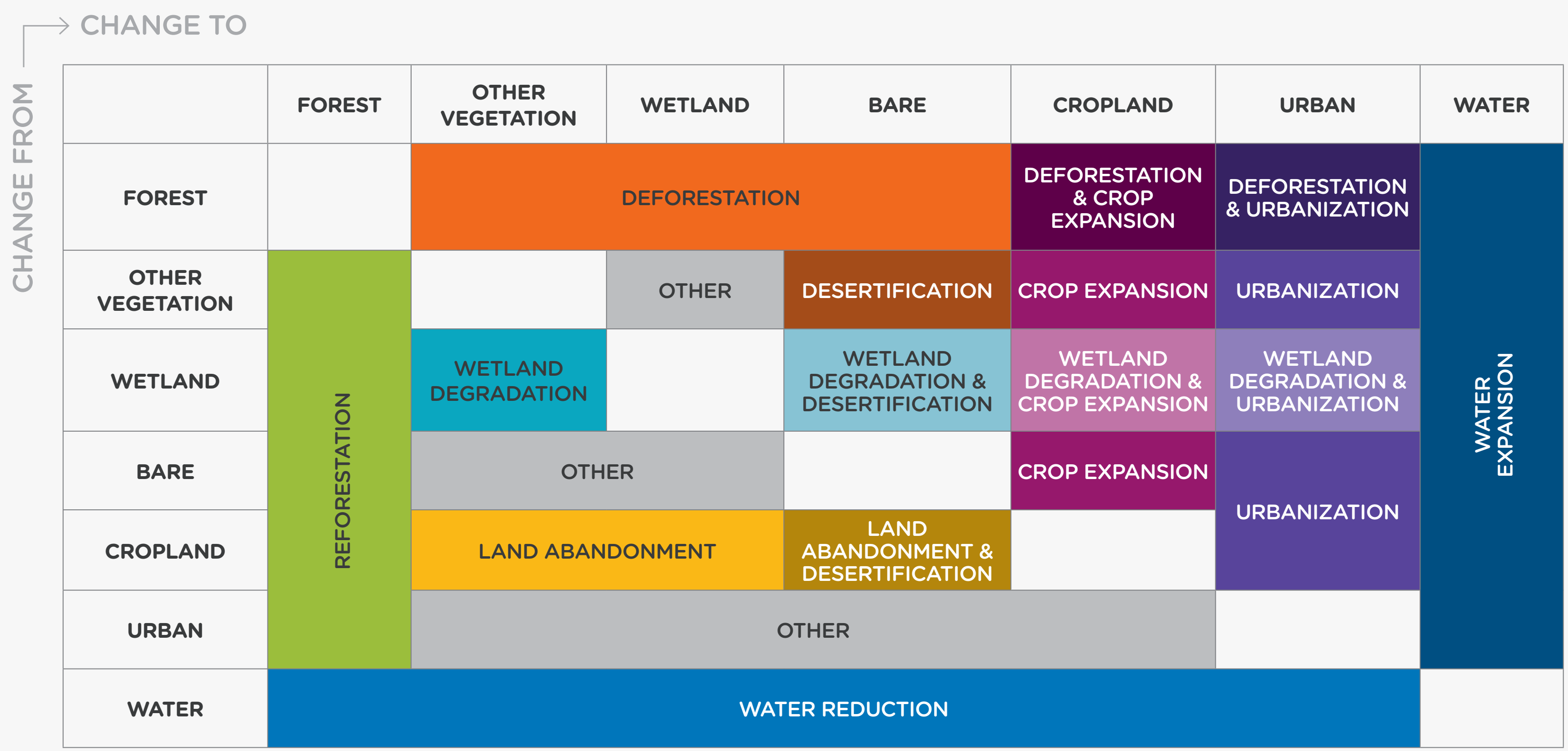
[92] Q-GIS software was used, which is a free and open-source cross-platform GIS software application that supports viewing, editing, and analysis of geospatial data. Discover QGIS

[93] RStudio is an Integrated Development Environment (IDE) for R, a programming language for statistical computing and graphics. About RStudio - RStudio

[94] The U.N. Climate report's five futures – decoded. Explainer: The U.N. climate report's five futures - decoded | Reuters

[95] Climate Change Knowledge Portal (CCKP). About us | Climate Change Knowledge Portal (worldbank.org)

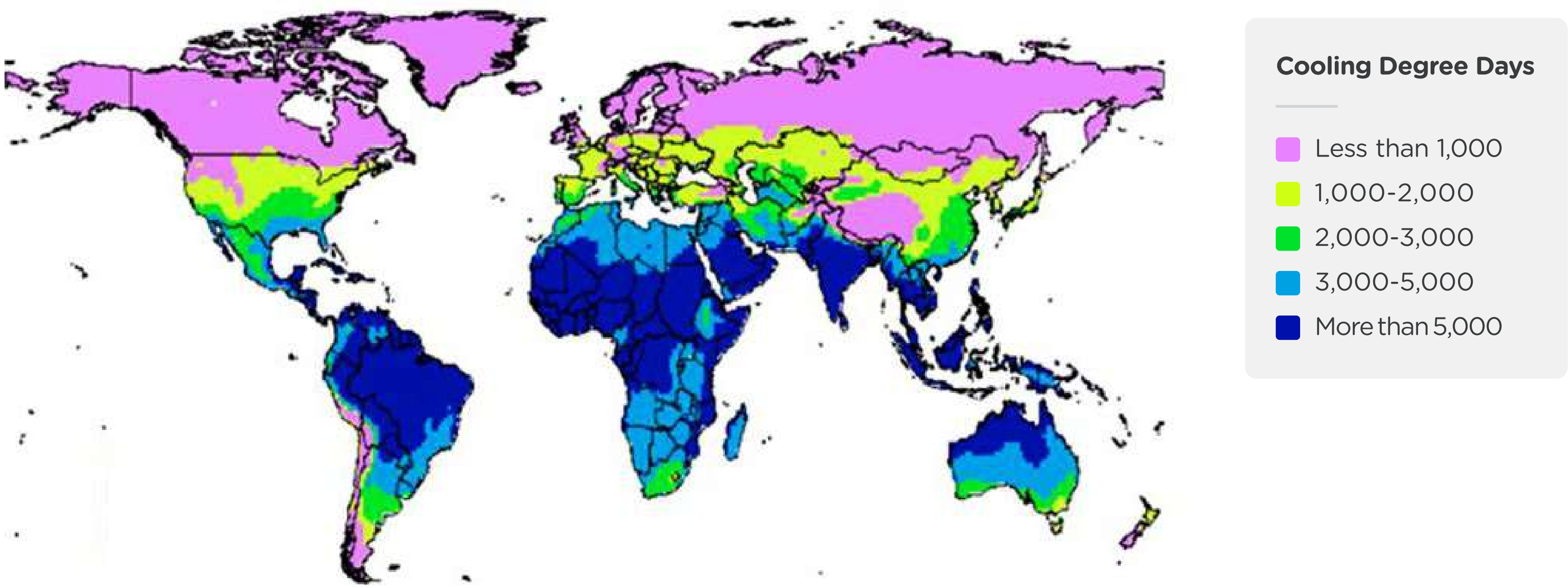
FIGURE 2.25: ANNUAL CHANGE OCCURRENCE AND CHANGE PROCESSES



Urban land use and heat analysis in major cities of the Critical 9 countries

The analysis covers the most populous cities in each of the Critical 9 countries for access to cooling. As urbanization grows, areas of these cities with vegetation and green spaces are seeing increased buildup that has compounding effects. Adding density implies an increase in the UHIE through the use of active cooling equipment. When buildup comes at the expensive of natural heat sinks such as green space and water, the effect is multiplied, creating additional risk for the most vulnerable populations.

FIGURE 2.26: COOLING DEGREE DAYS FROM BEST-PRACTICE POLICIES FOR LOW ENERGY AND CARBON BUILDINGS[96]



[96] Ürge-Vorsatz, D., Petrichenko, K., Antal, M., Staniec, M., Labelle, M., Ozden, E., Labzina, E. Best-Practice Policies for Low Energy and Carbon Buildings. A Scenario Analysis. Research report prepared by the Center for Climate Change and Sustainable Policy (3CSEP) for the Global Buildings Performance Network. May 2012.

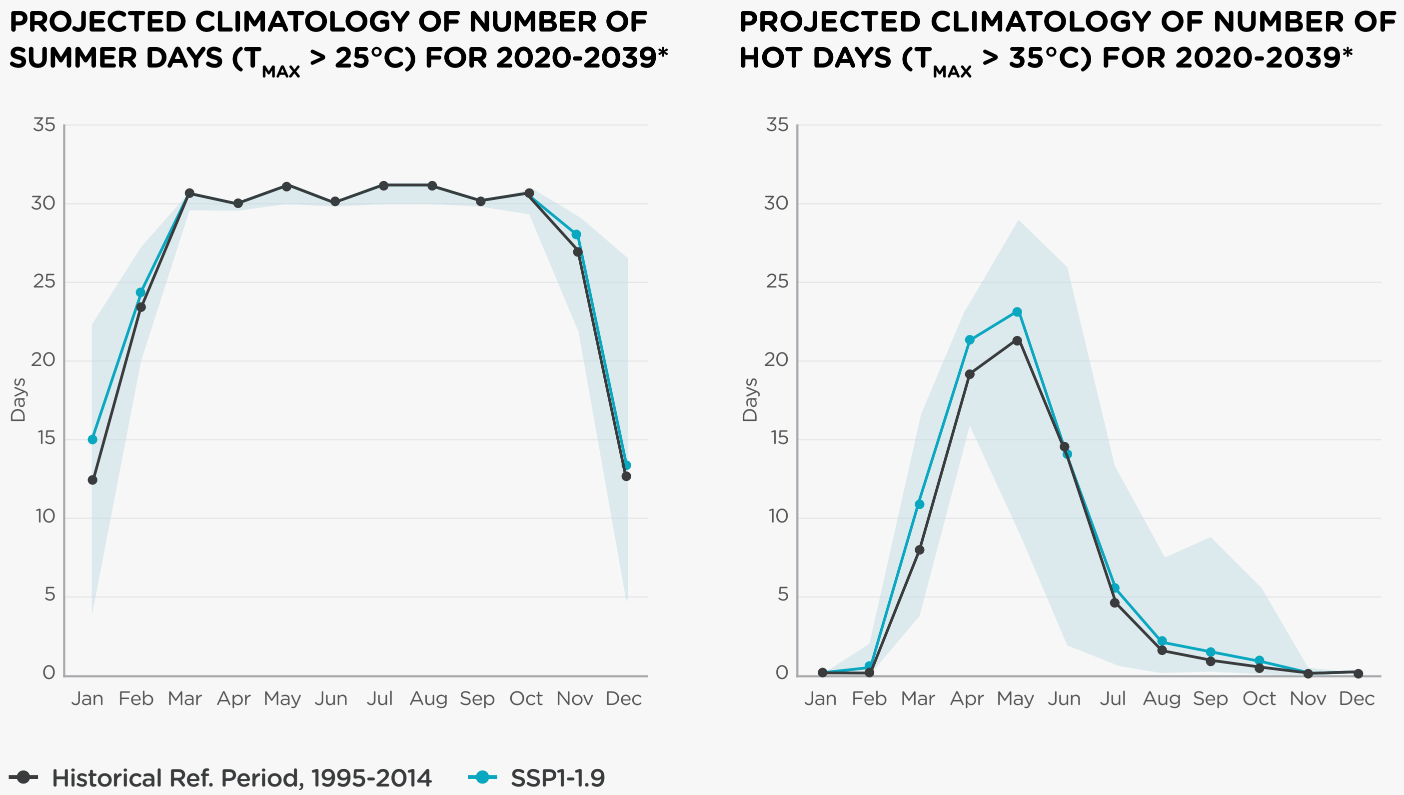
DHAKA

BANGLADESH

POPULATION

- **2015:** 17,597,000
- **2019:** 20,284,000
- **PRESENT:** 22,265,410

VIEW INTERACTIVE MAP →



*Dhaka, Bangladesh; (Reference Period: 1995-2014), SSP1-1.9, Multi-Model Ensemble

Source: Climate Change Knowledge Portal, The World Bank Group, 2022

Between 2015 and 2019, Dhaka added 0.93 square kilometers of built-up area for domestic and commercial use. This buildup came at the expense of 0.27 square kilometers of herbaceous vegetation, 0.44 square kilometers of cultivated and managed vegetation, and 0.1 square kilometers of herbaceous wetland.

Dhaka is expected to experience sustained high temperatures above 25°C in the most optimistic scenario, and a significant number of dangerous heat days over 35°C between March and June annually. The loss of cultivated land for fruits and vegetables not only implies a reduced ability to grow crops locally, but also diminishes the resilience of a growing urban population to the dangers of extreme heat. Understanding this impact and placing emphasis on urban greening and land to cultivate produce is likely to benefit both the UHIE in the city as well as food security.

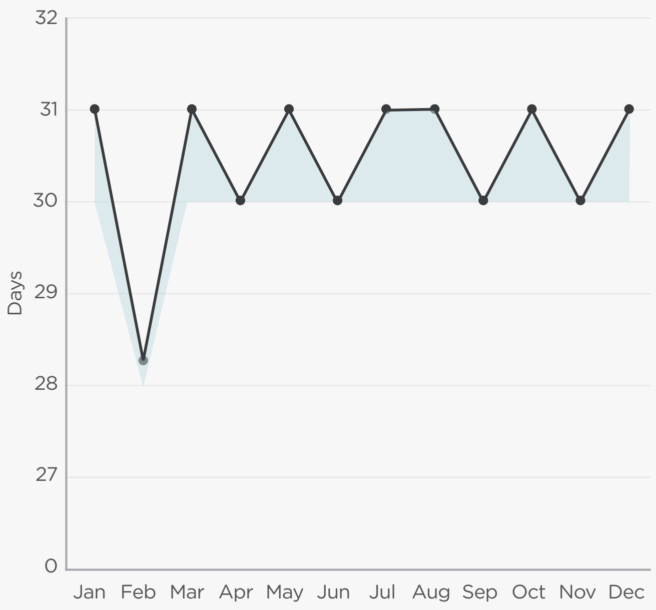
JAKARTA
INDONESIA

POPULATION

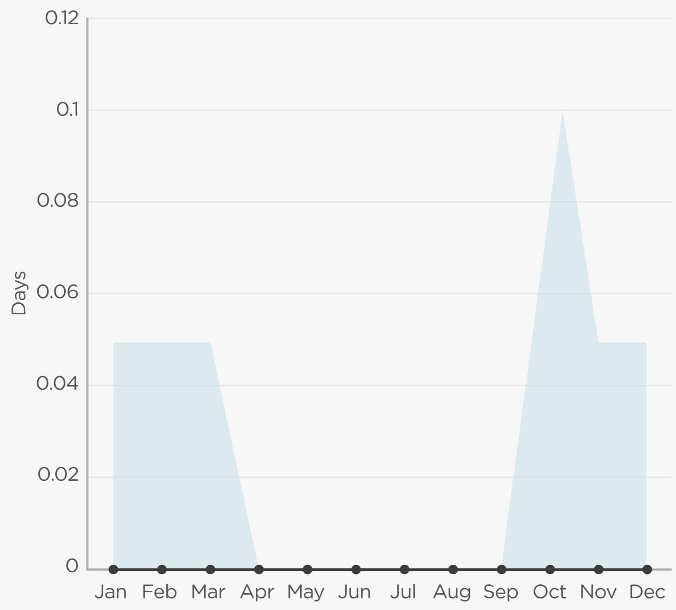
- **2015:** 10,173,000
- **2019:** 10,639,000
- **PRESENT:** 11,028,848

VIEW INTERACTIVE MAP →

PROJECTED CLIMATOLOGY OF NUMBER OF SUMMER DAYS (T_{MAX} > 25°C) FOR 2020-2039*



PROJECTED CLIMATOLOGY OF NUMBER OF HOT DAYS (T_{MAX} > 35°C) FOR 2020-2039*



Historical Ref. Period, 1995-2014   SSP1-1.9

*DKI Jakarta, Indonesia; (Reference Period: 1995-2014), SSP1-1.9, Multi-Model Ensemble

Source: Climate Change Knowledge Portal, The World Bank Group, 2022

Between 2015 and 2019, Jakarta increased its built-up area by 0.87 square kilometers at the expense of 0.25 square kilometers of herbaceous vegetation, 0.19 square kilometers of cultivated and managed vegetation, and 0.1 square kilometers each of bare/sparse vegetation and water bodies. This process also included the removal of 0.14 square kilometers of open forest that would have had a passive cooling effect on urban areas.

These changes were driven by increasing urbanization, but in combination with a growing number of days above 25°C annually, are likely to exacerbate the UHIE in the city. Even though Jakarta is not projected to have many days with dangerous heat (above 35°C), this trend will lead to increased cooling needs that could dramatically increase energy demand if met with inefficient, active cooling technologies. An expansion of green urban areas through land-use planning would help reverse these losses and reduce heat stress felt by vulnerable residents on high-temperature days.

KARACHI
PAKISTAN

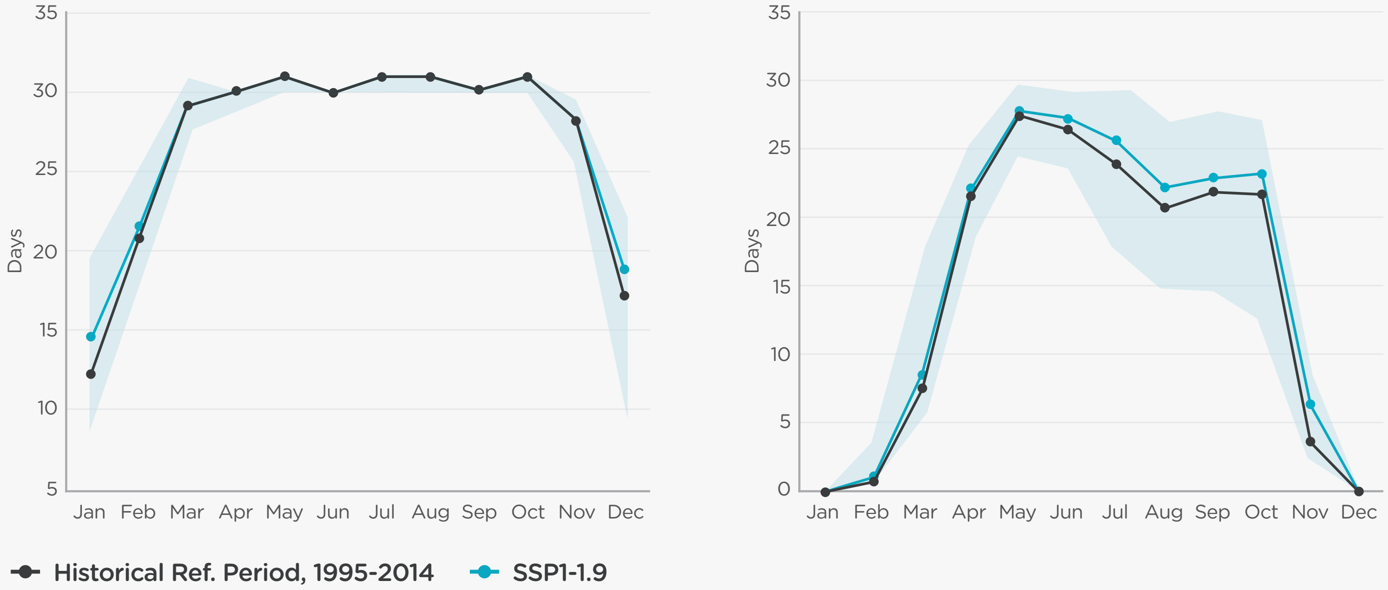
POPULATION

- **2015:** 14,289,000
- **2019:** 15,741,000
- **PRESENT:** 16,730,070

VIEW INTERACTIVE MAP →

PROJECTED CLIMATOLOGY OF NUMBER OF SUMMER DAYS (T_{MAX} > 25°C) FOR 2020-2039*

PROJECTED CLIMATOLOGY OF NUMBER OF HOT DAYS (T_{MAX} > 35°C) FOR 2020-2039*



Between 2015 and 2019, Karachi gained 6.63 square kilometers of built-up area at the expense of 1.82 square kilometers of shrubs, 0.18 square kilometers of herbaceous vegetation, 0.31 square kilometers of cultivated and managed vegetation, 3.6 square kilometers of bare or sparse vegetation, and 0.74 square kilometers of open forest.

Karachi made significant changes to its land-use patterns between 2015 and 2019, which has implications for food safety, agricultural production and thermal comfort. While the built-up area increased by 6.63 square kilometers, land used for the cultivation and management of vegetation grew by significantly larger amount, 213 square kilometers. This provides the city with resources to grow its local food supply system, benefiting residents and farmers through better food security and enhanced agricultural incomes, though there is a need for an expansion of the local cold chain to reduce potential post-harvest losses. With Karachi set to experience a high number of days with dangerous heat between April and October every year, further urban planning efforts to reduce the UHIE and reliance on inefficient, mechanical cooling would especially benefit the most vulnerable urban dwellers.

*Sindh, Pakistan; (Reference Period: 1995-2014), SSP1-1.9, Multi-Model Ensemble

Source: Climate Change Knowledge Portal, The World Bank Group, 2022

LAGOS
NIGERIA

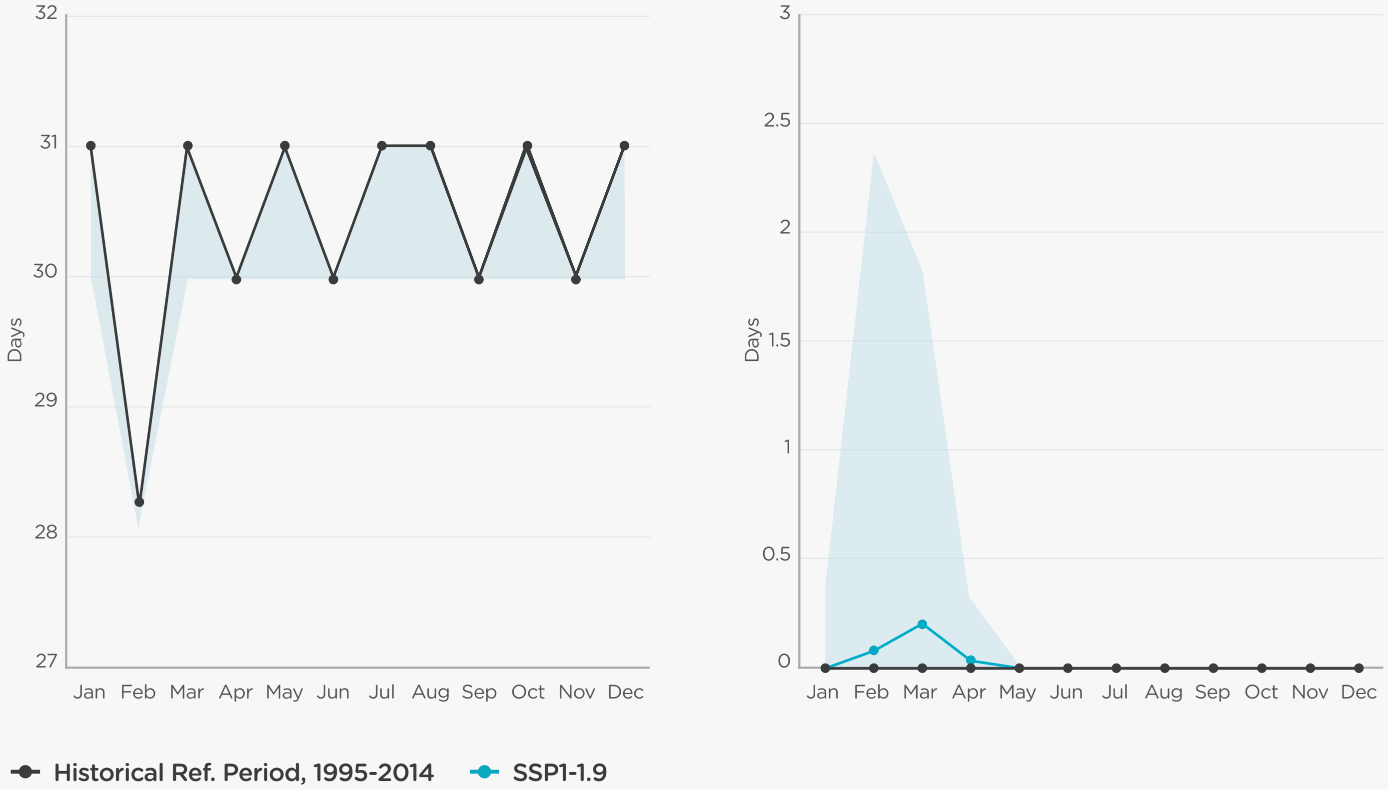
POPULATION

- **2015:** 12,239,000
- **2019:** 13,904,000
- **PRESENT:** 15,236,259

VIEW INTERACTIVE MAP →

PROJECTED CLIMATOLOGY OF NUMBER OF SUMMER DAYS (T_{MAX} > 25°C) FOR 2020-2039*

PROJECTED CLIMATOLOGY OF NUMBER OF HOT DAYS (T_{MAX} > 35°C) FOR 2020-2039*



***Lagos, Nigeria; (Reference Period: 1995-2014), SSP1-1.9, Multi-Model Ensemble**

Source: Climate Change Knowledge Portal, The World Bank Group, 2022

Between 2015 and 2019, Lagos saw an increase of 0.43 square kilometers of built-up area. This came at the expense of 0.37 square kilometers of herbaceous vegetation, and marginal reductions in cultivated and managed vegetation, bare or sparse vegetation, water bodies and open forest.

Even in the most optimistic scenario, it is likely that there will be an increase in the number of days with dangerous heat (more than 35°C) per year for Lagos. Coupling this with rising sea levels, urbanization processes need to not only factor in human comfort and safety but also increased urban resilience.

MAPUTO
MOZAMBIQUE

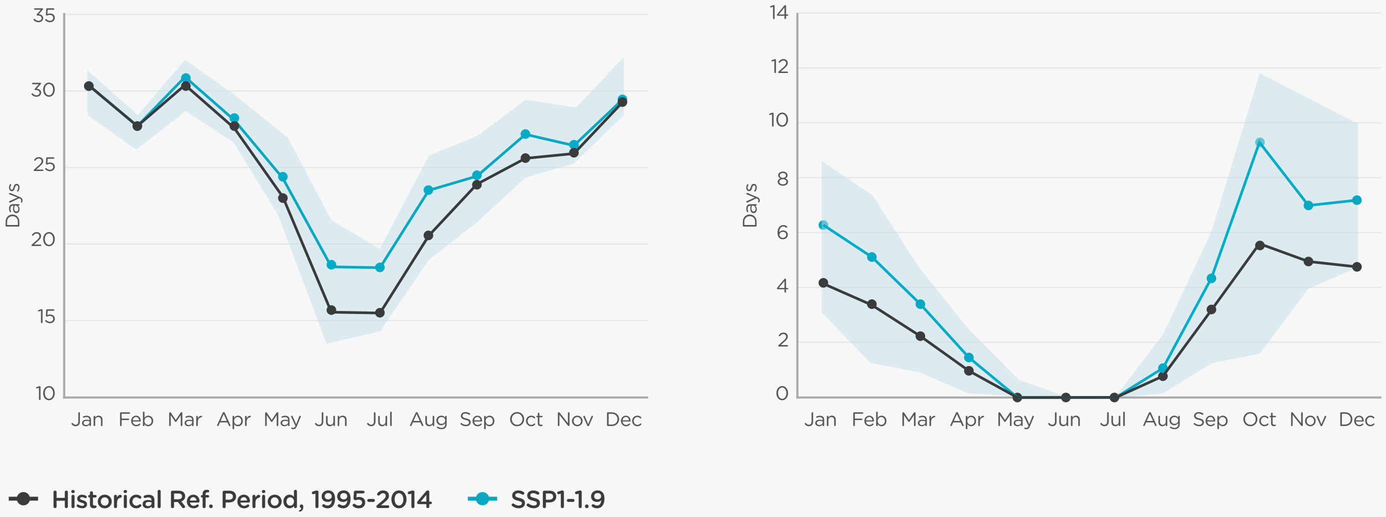
POPULATION

- **2015:** 1,100,000
- **2019:** 1,104,000
- **PRESENT:** 1,134,096

VIEW INTERACTIVE MAP →

PROJECTED CLIMATOLOGY OF NUMBER OF SUMMER DAYS (T_{MAX} > 25°C) FOR 2020-2039*

PROJECTED CLIMATOLOGY OF NUMBER OF HOT DAYS (T_{MAX} > 35°C) FOR 2020-2039*



Between 2015 and 2019, Maputo increased its built-up area by 0.3 square kilometers and lost 0.12 square kilometers of herbaceous vegetation, as well as marginal amounts of shrubs, cultivated and managed vegetation, water bodies and open forest.

Mozambique does not have a large urban population — 63 percent of its people still live in rural areas —[97] and this is reflected in the observed land-use changes. But the city is planning for expansion, including through the Maputo Urban Transformation Project.[98] It is expected to see over four days of dangerous heat (+35°C) annually between September and February, presenting urban planners in Maputo with a unique opportunity to plan early for the increasing effects of heat, for example through natural heat sinks, increased green spaces and improved passive cooling measures.

***Maputo, Mozambique; (Reference Period: 1995-2014), SSP1-1.9, Multi-Model Ensemble**

Source: Climate Change Knowledge Portal, The World Bank Group, 2022

[97] Rural population – Mozambique, The World Bank, 2022. Rural population (% of total population) - Mozambique | Data (worldbank.org)

[98] Mozambique Receives $100 Million for its Maputo Urban Transformation Project, The World Bank, 2020. Mozambique Receives $100 Million for its Maputo Urban Transformation Project (worldbank.org)

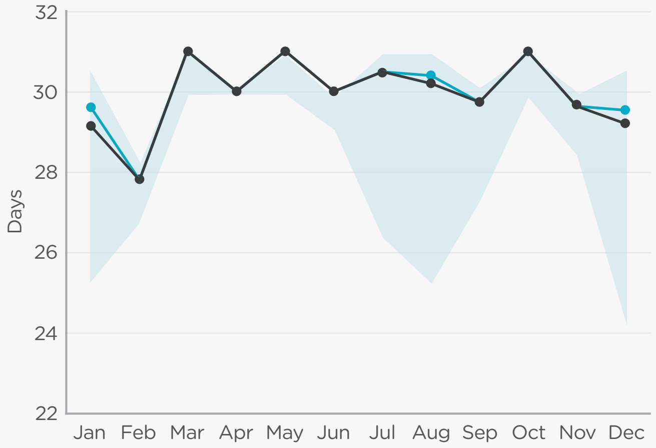
MUMBAI
INDIA

POPULATION

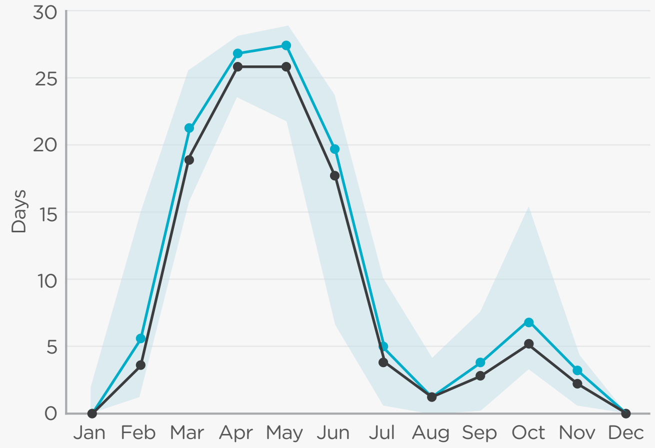
- **2015:** 19,316,000
- **2019:** 20,185,000
- **PRESENT:** 20,876,486

VIEW INTERACTIVE MAP →

PROJECTED CLIMATOLOGY OF NUMBER OF SUMMER DAYS (T_{MAX} > 25°C) FOR 2020-2039*



PROJECTED CLIMATOLOGY OF NUMBER OF HOT DAYS (T_{MAX} > 35°C) FOR 2020-2039*



Historical Ref. Period, 1995-2014 SSP1-1.9

*Maharashtra, India; (Reference Period: 1995-2014), SSP1-1.9, Multi-Model Ensemble

Source: Climate Change Knowledge Portal, The World Bank Group, 2022

Between 2015 and 2019, Mumbai gained 0.9 square kilometers of built-up area at the expense of 0.14 square kilometers of herbaceous vegetation, 0.14 square kilometers of cultivated and managed vegetation, 0.28 square kilometers of closed forest, 0.16 square kilometers of open forest, and lesser amounts from shrubs, bare/sparse vegetation and water bodies.

Each year large segments of India's population move to Mumbai from rural areas for social, economic and environmental opportunities. This migration has contributed to the expansion of informal settlements, including the Dharavi slum that is now home to more than 1 million people.[99] With projections for at least 15 days per month of dangerous heat between March and June each year, these people will be increasingly vulnerable to a lack of access to cooling. Heat-action planning, and public cooling centres are among the types of low-cost solutions that can help meet their cooling needs. So too is urban greening, which was prioritized by the Government of Maharashtra in its recent climate change action plan.[100]

[99] Urbanization in contrasting cities, BBC, 2022. Consequences of urbanisation in Mumbai - Urbanisation in contrasting cities – WJEC - GCSE Geography Revision - WJEC - BBC Bitesize

[100] The Hindu, 18 March 2022, Link.

OMDURMAN
SUDAN

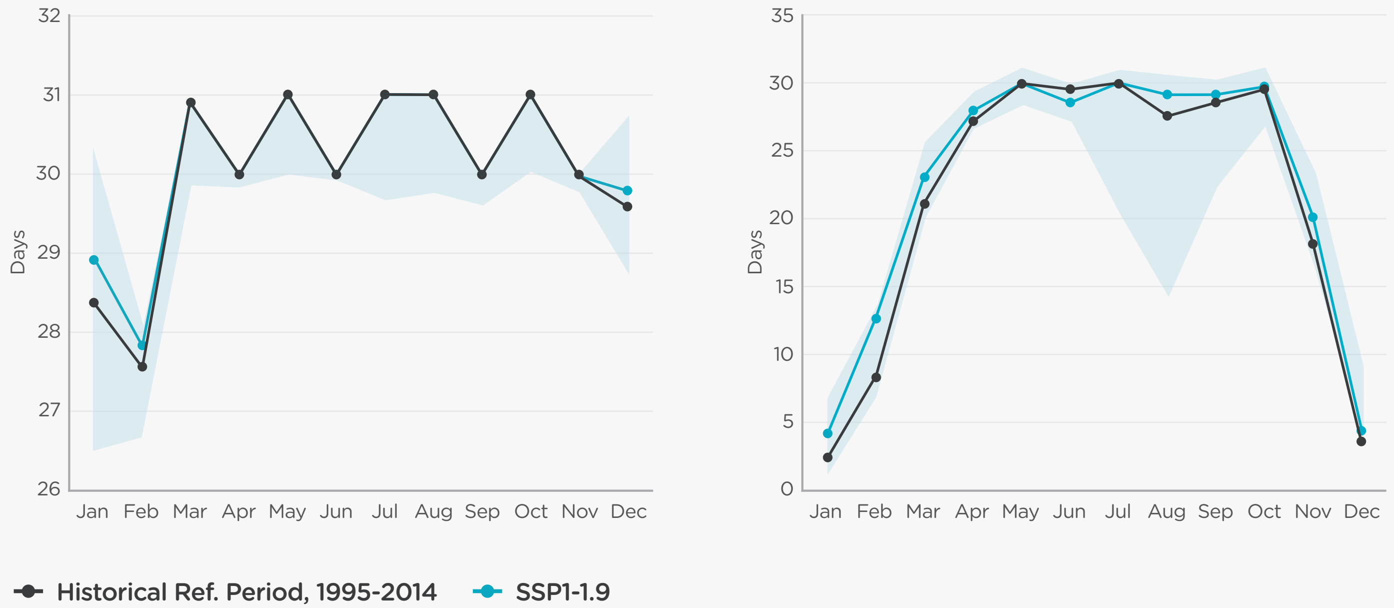
POPULATION

(Reliable data not available)

VIEW INTERACTIVE MAP →

PROJECTED CLIMATOLOGY OF NUMBER OF SUMMER DAYS (T_{MAX} > 25°C) FOR 2020-2039*

PROJECTED CLIMATOLOGY OF NUMBER OF HOT DAYS (T_{MAX} > 35°C) FOR 2020-2039*



*Khartoum, Sudan; (Reference Period: 1995-2014), SSP1-1.9, Multi-Model Ensemble

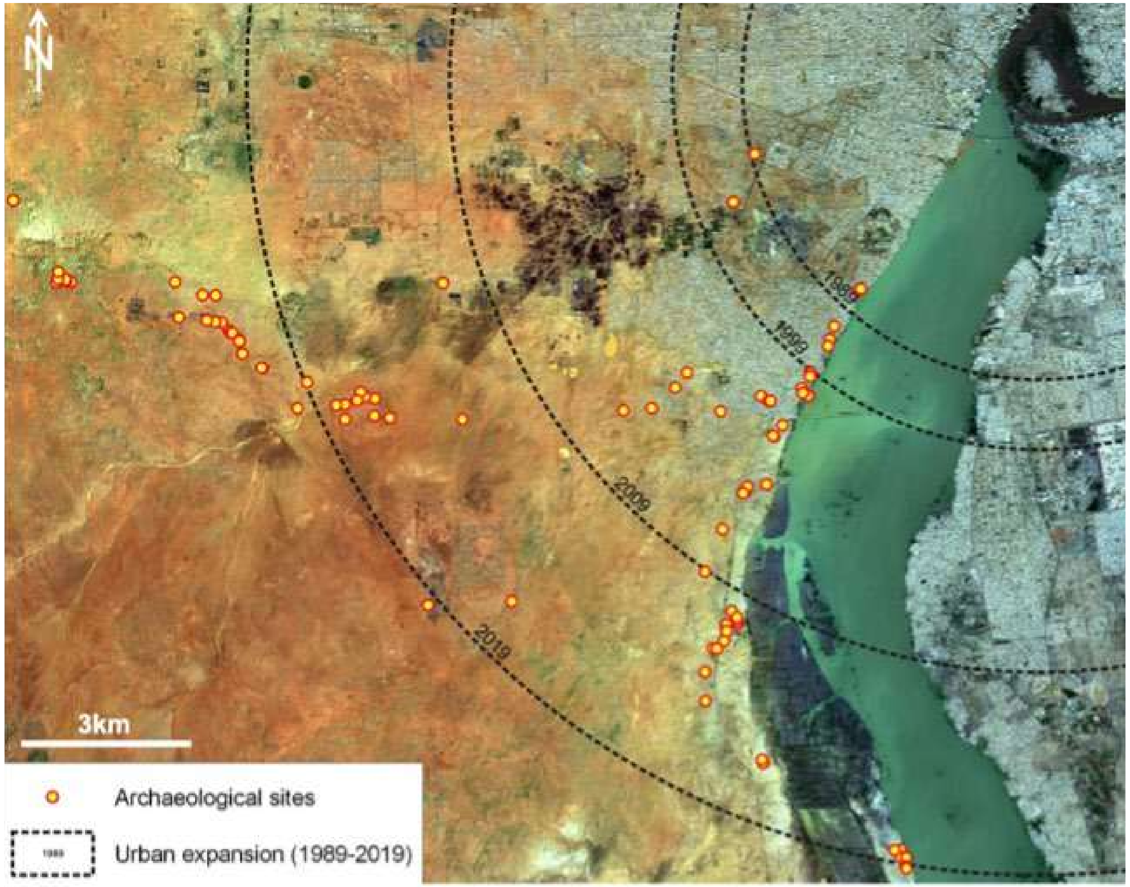
Source: Climate Change Knowledge Portal, The World Bank Group, 2022

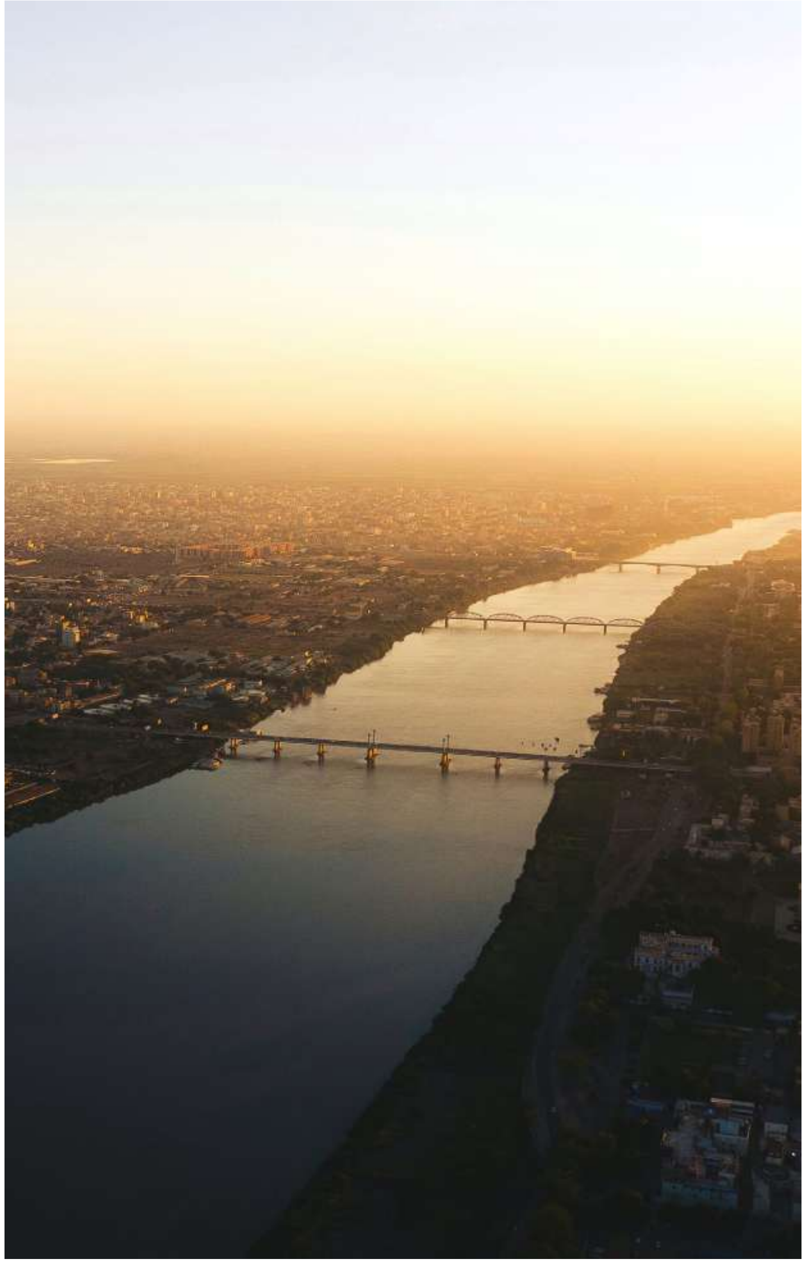
Between 2015 and 2019, Omdurman gained 0.48 square kilometers of built-up area at the expense of bare or sparse vegetation typical to the climate of the region.

The Omdarman-Khartoum region has grown rapidly over the past three decades and is projected to see over 20 days per month of dangerous heat between April and October annually between 2020 and 2039. In addition to heat, increased flooding over the past decade has also created challenges for urban residents.[101] With this in mind, the city has a unique opportunity to use urban planning and expansion processes to mitigate both urban heat and flooding risks at the same time, leveraging its water resources for nature-based urban cooling.

[101] Andrea Zerboni et. al (2021) The Khartoum-Omdurman conurbation: a growing megacity at the confluence of the Blue and White Nile Rivers, Journal of Maps, 17:4, 227-240, DOI: 10.1080/17445647.2020.1758810

FIGURE 2.27: SATELLITE IMAGE SHOWING URBAN EXPANSION AND ARCHAEOLOGICAL SITES IN THE OMDURMAN-KHARTOUM REGION





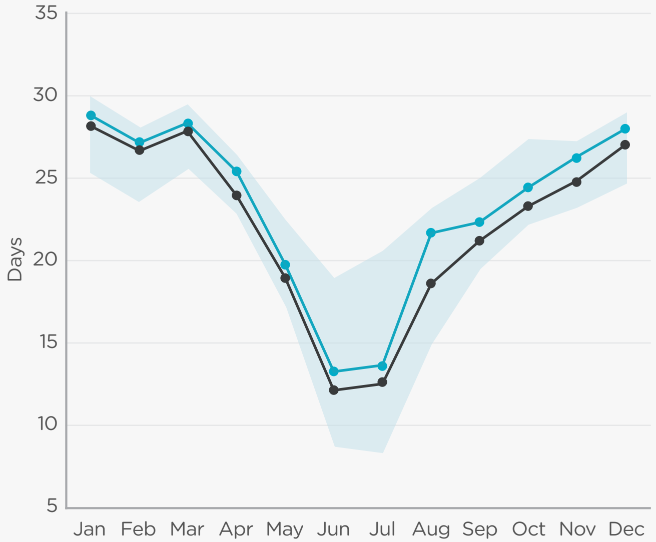
SÃO PAULO
BRAZIL

POPULATION

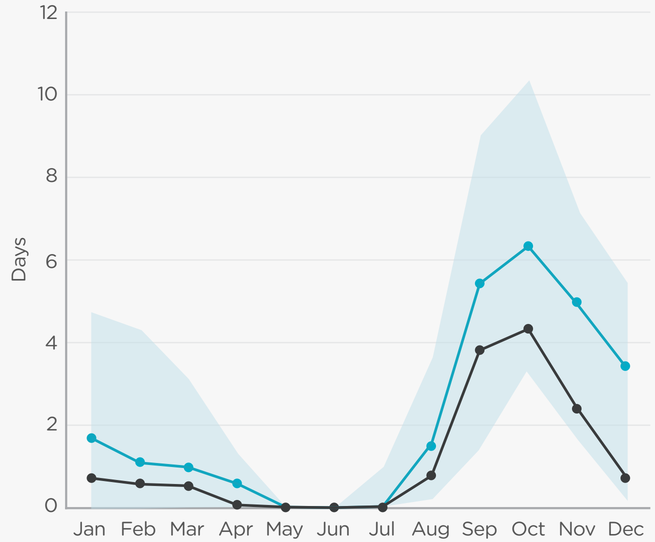
- **2015:** 20,883,000
- **2019:** 21,847,000
- **PRESENT:** 22,374,333

VIEW INTERACTIVE MAP →

PROJECTED CLIMATOLOGY OF NUMBER OF SUMMER DAYS (T_{MAX} > 25°C) FOR 2020-2039*



PROJECTED CLIMATOLOGY OF NUMBER OF HOT DAYS (T_{MAX} > 35°C) FOR 2020-2039*



Historical Ref. Period, 1995-2014 SSP1-1.9

***São Paulo, Brazil; (Reference Period: 1995-2014), SSP1-1.9, Multi-Model Ensemble**

Source: Climate Change Knowledge Portal, The World Bank Group, 2022

Between 2015 and 2019, São Paulo, Brazil increased its built-up area by 2.27 square kilometers and reduced its area of herbaceous vegetation by 1.1 square kilometers and its area of open forest by 1.03 square kilometers. The city also saw small reductions in its areas of cultivated and managed vegetation, bare or sparse vegetation, herbaceous wetland and closed forest.

In São Paulo, rapid urbanization is increasing the number of people living in informal settlements known as *favelas*. These are typically constructed to a low standard, often by residents themselves, and are often located on wasteland, marshy land, or in flood-prone areas. The city experiences sustained temperatures above 25°C in the summer months and is also projected to see four days per month of dangerous heat between September and November every year, exposing these residents to significant risks from lack of access to cooling. Targeted efforts to mitigate these risks include land-use planning changes that prioritize green spaces near favelas, and heat-action planning that provides them with public cooling centres on days when temperatures exceed 35°C.

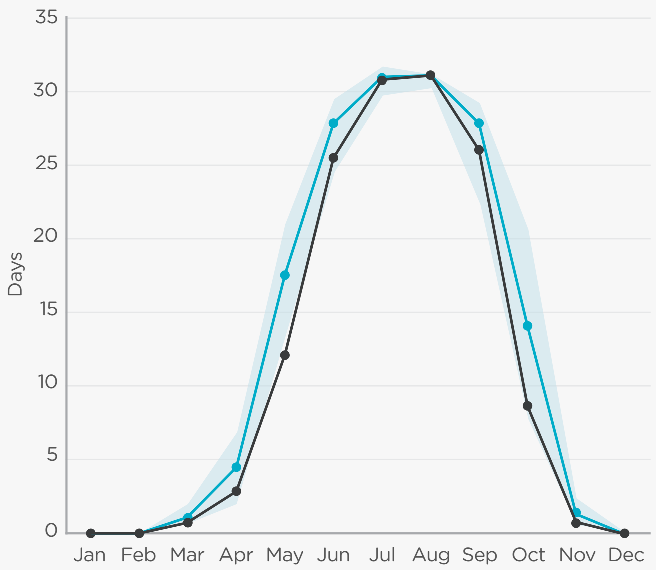
SHANGHAI
CHINA

POPULATION

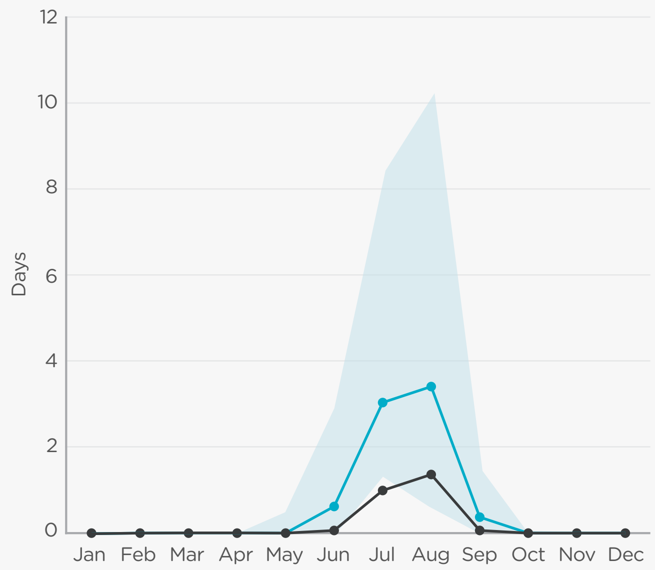
- **2015:** 23,482,000
- **2019:** 26,317,000
- **PRESENT:** 28,309,043

VIEW INTERACTIVE MAP →

PROJECTED CLIMATOLOGY OF NUMBER OF SUMMER DAYS (T_{MAX} > 25°C) FOR 2020-2039*



PROJECTED CLIMATOLOGY OF NUMBER OF HOT DAYS (T_{MAX} > 35°C) FOR 2020-2039*



Historical Ref. Period, 1995-2014 SSP1-1.9

*Shanghai Shi, China; (Reference Period: 1995-2014), SSP1-1.9, Multi-Model Ensemble

Source: Climate Change Knowledge Portal, The World Bank Group, 2022

Between 2015 and 2019, Shanghai increased its built-up area by 8.96 square kilometers with a decrease of 0.78 square kilometers of shrubs, 1.32 square kilometers of herbaceous vegetation, 3.48 square kilometers of cultivated and managed vegetation, 0.16 square kilometers of herbaceous wetland, 0.16 square kilometers of open forest with evergreen broad leaf, and 3.38 square kilometers of open forest.

Shanghai has observed the highest increase in its built-up area among the major cities in the Critical 9 countries. The increase contributes to increased demand for air-conditioning and refrigeration systems, highlighting the need for energy-efficient and climate-friendly technologies. Demand can be expected to be particularly high in July and August, where temperatures are projected to exceed 35°C for three days each month. For its most vulnerable residents, green spaces, passive cooling, and more vegetation can provide relief while reducing the UHIE and minimizing the energy necessary for cooling needs.

CHILLING PROSPECTS

CHAPTER THREE

Tracking the Enabling Environment for Sustainable Cooling

Delivering enhanced access to sustainable cooling solutions depends on a broad variety of enabling factors. This chapter of *Chilling Prospects* focuses on three of these factors:

- Policy Progress
- Financial Flows
- Community of Practice

Policies on sustainable cooling have made important progress since the Kigali Amendment, including national commitments in Nationally Determined Contributions (NDCs) and National Cooling Action Plans (NCAPs), with increased focus turning to sectoral policies that are crucial to enhancing investment. Similarly, finance has begun to flow, and while delivery of sustainable solutions will require leadership from the private sector, public finance, including climate finance, is now working to address sustainable cooling in earnest. Underpinning this is a growing community of practice that is displaying the benefits of collaboration and knowledge sharing given limited resources and complex problems, with new partnerships, awareness raising, and information sharing among and outside this community remaining a key need.

3.1 Sustainable Cooling Policy Progress

The combination of affordable, active and passive technology, services, finance, and policy solutions constitute the basic solution pillars to create an enabling environment for sustainable cooling. For the first time, the *Chilling Prospects* series provides a deep dive on the policy progress for sustainable cooling, with an assessment of progress for the Critical 9 countries.[1]

Ultimately, tracking progress aims to trigger action to:

- Bridge the policy gap across the Cooling for All needs
- Foster dialogue to boost collaboration and cooperation
- Engage diverse stakeholders in a community of practice
- Integrate sustainable cooling in national energy and energy efficiency strategies and catalyze investments.
- Achieve the Kigali Amendment, Paris Agreement, and Sustainable Development Goals (SDGs) 2, 3, 7 and 13

Cooling for All Policy Tracking

Policy tracking includes assessing current policy for: **(i) access to cooling; (ii) energy efficiency for air conditioners, fans, refrigerators and buildings; and (iii) climate change policies for cooling** across the three Cooling for All needs (food, nutrition and agriculture; health services; and human comfort and safety). Specifically, the assessment includes a checklist of policies (regulatory, information and incentive) covering air conditioners, fans, refrigerators, passive cooling in buildings, and agricultural and vaccine cold chains. The country-by-country assessment is made by integrating findings from Sustainable Energy for All (SEforALL) partners, including the CLASP Policy Resource Center, World Bank RISE indicators and national publicly available resources.

[1] The *Critical 9* refers to the top nine high-impact countries for access to cooling. They are: Bangladesh, Brazil, China, India, Indonesia, Mozambique, Nigeria, Pakistan and Sudan.

TABLE 3.1: COOLING FOR ALL POLICY TRACKING APPROACH

WHAT IS THE STATUS OF THE NCAP? (NOT PLANNED, UNDER DEVELOPMENT, PUBLISHED)		
ACCESS TO COOLING **To what extent do policies enhance access to cooling?**	**ENERGY EFFICIENCY FOR COOLING** **To what extent do policies enhance efficiency of ACs, fans, refrigerators and buildings?**	**CLIMATE MITIGATION FROM COOLING** **To what extent is cooling reflected in climate targets?**
• Does the NCAP consider improved access to cooling? • Is cooling demand considered in electrification planning? • Are there government programmes for off-grid refrigerators, ACs and/or fans? • Is the ownership rate of refrigerators, ACs and/or fans available? (through national surveys or other national initiatives?) • Are there financial incentives for the purchase of refrigerators, ACs and/or fans? • Is there an assessment of vaccine cold chain infrastructure? • Are agricultural cold chains recognized in a national strategy or implementation policy for sustainable cooling? • Is passive cooling recognized in the national building code or other national strategy or implementation policy for sustainable cooling?	• Are there energy services agreements (energy performance contracts)? • Have minimum energy performance standards been adopted for refrigerators, ACs and fans? • Is there a policy for regulating efficiency of imported refrigerators, ACs and/or fans? • Has energy-efficiency labelling been adopted for refrigerators, ACs and/or fans? • Is energy-efficiency labelling for refrigerators, ACs and/or fans mandatory? • Are there energy-efficiency codes for new residential and/or commercial buildings? • Are there energy-efficiency codes for existing residential and/or commercial buildings? • Are energy-efficiency codes mandatory? • Are there financial incentives for efficient cooling in buildings? • Are there non-financial incentives for efficient cooling in buildings?	• Is cooling considered in the NDCs? • Has the Kigali Amendment been ratified?

This policy tracking effort helps to identify progress and gaps in the policy framework for sustainable cooling across key cooling needs. It can be used in combination with Cooling for All tools, including the Cooling for All Needs Assessment, which helps governments, local authorities and stakeholders to assess the full spectrum of cooling needs in terms of food, nutrition and agriculture; health services; and human comfort and safety to inform policy action. The This is Cool Solutions directory and toolkit can further help policymakers and practitioners to match solutions to bridge gaps in policy, finance, services and technology.

SEforALL welcomes further support and data from partners and governments to expand the scope and accuracy of this policy tracking, including in more aspects of the policy landscape and for additional countries. To get involved or provide data, please contact the Cooling for All team at coolingforall@seforall.org.

3.1.1 Policies on access to cooling

Access to sustainable cooling solutions is a necessity for effective adaptation to climate change, especially for those areas and population groups that are most vulnerable to the effect of rising global temperatures. Cooling policies regulate or support the delivery of cooling solutions — active and passive — that are environmentally sustainable, efficient, affordable and commercially viable to meet cooling needs for food, nutrition and agriculture; health services; and human comfort and safety. Policies that enhance access to cooling are identified within national electrification strategies, data collection frameworks for cooling devices, and financial incentives or government programmes that bridge the affordability gap for cooling devices.

Across the Critical 9 countries, data quantifying access to sustainable cooling remain scarce, but information on policy signals is more readily available. The analysis shows, for example, that cooling demand is not generally reflected in electrification planning, with only Bangladesh having recognized it (Figure 3.1). Financial incentives for the purchase of efficient on-grid refrigerators, air conditioners and fans are rarely available, and government programmes for off-grid devices could not be identified in any of the Critical 9 countries, nor were there financing mechanisms for such devices to support greater affordability, with anecdotal evidence suggesting that those that do exist are few and far between. Whether through an NCAP, National Energy Strategy, or Energy Efficiency strategy, price support and financial incentives are essential to increase the affordability of high-efficiency products, which would serve to meet the growing demand for cooling and manage its impact on power generation, transmission, and distribution planning. Off-grid, national electrification strategies could benefit from reflecting cooling needs, and government mechanisms for efficient air conditioners, fans and refrigerators can not only help meet cooling needs faster, but also ensure electrification progress is not slowed by growing energy needs for cooling, particularly in rural areas.

Among the Critical 9 countries, four have policies that support the expansion of passive cooling within their national energy policy, including Nigeria's building code and India's Cooling Action Plan. However, the implementation of such policies and plans is often lacking. Similarly, the policy tracking identifies opportunities for incorporating access to cooling. For instance, only three of the Critical 9 countries have NCAPs that consider improved access to cooling as a goal or target, meaning that there is an opportunity for the remaining countries to build it into their existing NCAPs or incorporate it from the beginning of the NCAP planning cycle.

Agricultural cold chains are recognized in policy in five of the Critical 9 countries but they are typically cited as a component of a sectoral development strategy. India's Cooling Action Plan includes plans for integrating agricultural cold chains with sectoral strategies. Seven of the Critical 9 countries have at least one immunization plan or vaccine cold chain management overview publicly available, although with varying degrees of depth and recency. lacking. Similarly, the policy tracking identifies opportunities for incorporating access to cooling. For instance, only three of the Critical 9 countries have NCAPs that consider improved access to cooling as a goal or target, meaning that there is an opportunity for the remaining countries to build it into their existing NCAPs or incorporate it from the beginning of the NCAP planning cycle.

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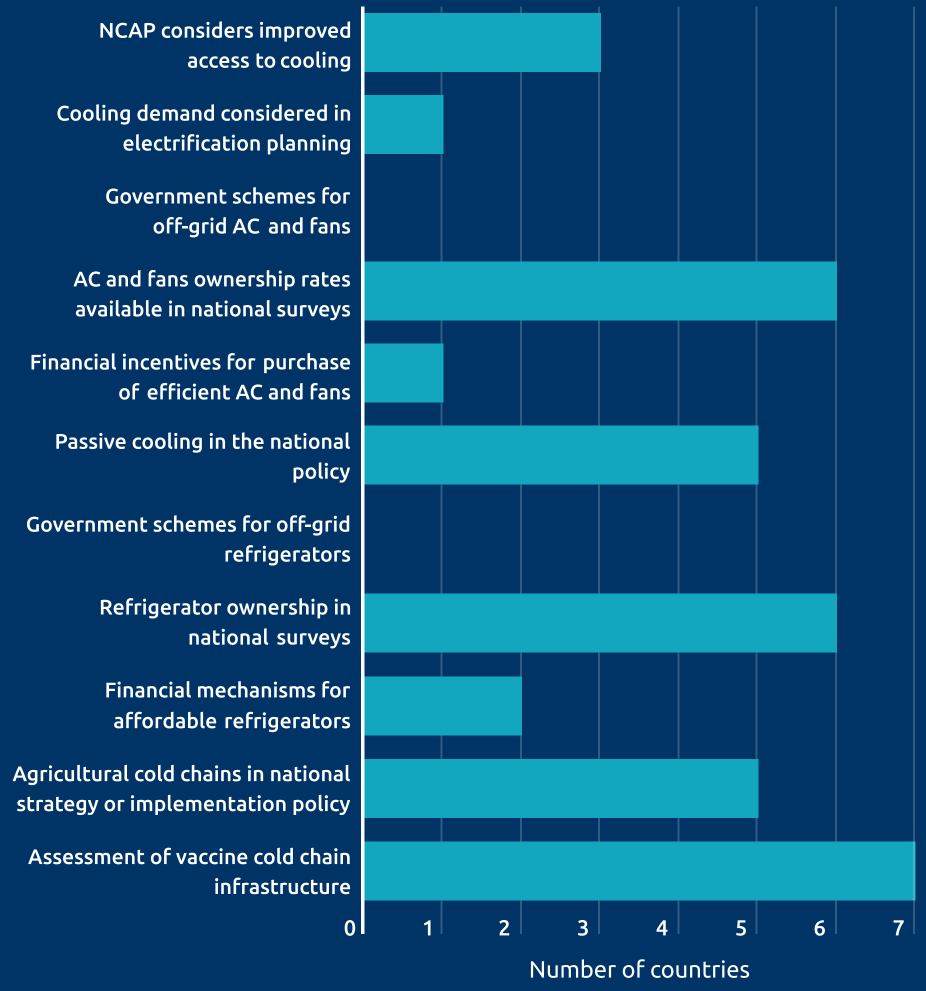
3.1.2 Energy efficiency for cooling policies

The assessment of energy efficiency for cooling policies is well-documented as public information is available across the Critical 9 countries and from partner resources. Minimum energy performance standards (MEPS) and labels for cooling appliances, both mandatory and voluntary, identified in this assessment only cover on-grid

FIGURE 3.1: INDICATORS FOR PROGRESS ON ACCESS TO COOLING POLICIES IN THE CRITICAL 9 COUNTRIES



products, implying a gap for the efficiency of devices with dedicated off-grid applications, which is particularly important for reaching isolated and rural populations.

Ensuring an optimal level for efficiency in MEPS and labels helps increase their efficacy, as well as the trust and support of the population for these instruments. If the energy-efficiency level of MEPS does not reflect the best available technologies, the efficacy of the policy and the affordability of high-efficiency units is likely to be suboptimal. Similar effects can occur when labels do not disclose relevant information to help consumers to choose high energy-performing products (HEPS). Therefore, it is essential that MEPS and labels recognize market changes and evolve accordingly.

Energy-efficiency policies for cooling technologies exist in all the Critical 9 countries but there are significant differences in their implementation and enforcement. MEPS for refrigerators, air conditioners and fans have yet to be adopted in Mozambique and Sudan, while Pakistan has MEPS only for fans, and Nigeria has neither refrigerator nor freezer MEPS. Similarly, Mozambique, Pakistan and Sudan have not adopted mandatory or voluntary energy-efficiency labelling.

Whether energy-efficiency policies are successful or not depends largely on the proper combination of information, regulation and incentives[2]. The enactment and enforcement of robust efficiency policies that cover refrigerants and compressors is key to avoid market dumping of inefficient and highly polluting products. Policymakers should not only set the policy framework but should also raise ambition and aim for improved product efficiency. For example, recent studies show that best-in class air conditioners available worldwide can achieve energy-efficiency ratios (EER) of 5.0–6.5 W/W.[3,4] This is significantly above

[2] The Future of Cooling (2018). IEA. Link.

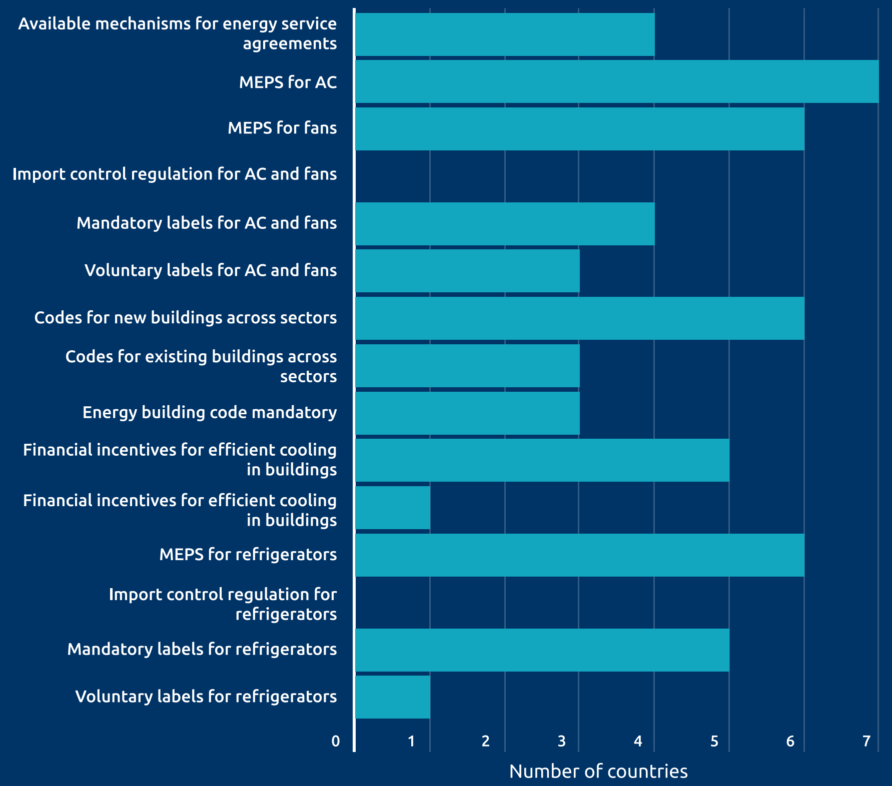
[3] The energy-efficiency ratio (EER) is used to measure energy-efficiency performance for air conditioners. According to ISO 5151:2017, it is defined as the total cooling capacity divided by the device's effective power input under any set of rating conditions). The higher the EER, the more efficient the air conditioner.

[4] Efficiency for RACs. N. Shah, W.Y. Park, Trends in best-in-class energy-efficient technologies for room air conditioners (2021). Link.

the minimum required efficiency ratios in most countries, including several countries in Africa, where they are below 3.0 W/W.

The Critical 9 countries have made insufficient progress or lack data on energy-efficiency regulations for imported air conditioners, fans and refrigerators (Figure 3.2).

FIGURE 3.2: ENERGY-EFFICIENT COOLING POLICIES IN THE CRITICAL 9 COUNTRIES



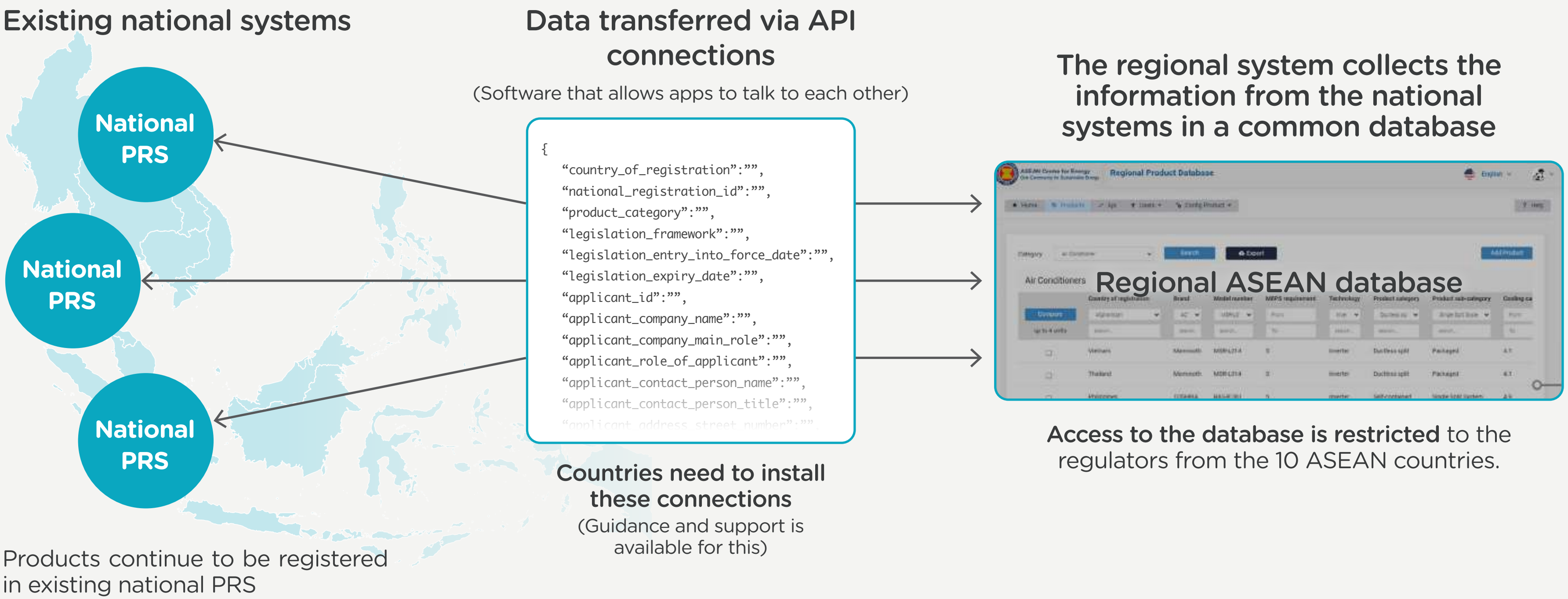
HARMONIZATION OF PRODUCT REGISTRATION ACTIVITIES IN ASEAN COUNTRIES

In many developing countries inefficient products are in circulation and causing added strain on the electricity grid. A key tool to transform the markets to energy-efficient products are Product Registration Systems (PRSs), which are needed to ensure the effective implementation and regular update of MEPS and product labelling.

United for Efficiency (U4E), an initiative of the UN Environment Programme (UNEP), the ASEAN Centre for Energy (ACE), the International Institute for Energy Conservation (IIEC) and the ASEAN countries have created a product registration database that harmonizes product registration activities in the region to convert the market to energy-efficient lighting, refrigeration and air conditioners. The leveraging effect of regional coordination enables governments to significantly reduce costs for product registry activities and enhances the enforcement of the regulations in place while avoiding dumping. In addition, a prototype national PRS has been developed that can be used by countries in the region that currently do not have a PRS in place. The product registration framework is built on best practices and can also be implemented by other countries and regions. It includes a modular design that enables users to individualize the systems and is also designed to work with slow connections and data requests. The system aligns with the Kigali Amendment and ensures a holistic transition not only to energy-efficient products but also to low Global Warming Potential (GWP) refrigerants.

It is predicted that by 2040, Southeast Asia will account for one of the largest growth rates of electricity used for cooling appliances.[5] According to [U4E's Country Saving Assessments](), which show the benefits of higher product efficiency, electricity consumption used for air conditioners alone is expected to almost double in the ASEAN region by 2040. U4E estimates that with energy-efficient air conditioners, refrigerators and lighting, the region could save over 160 TWh by 2040, which is equivalent to over 100 million tonnes of CO2, 66 large power plants and USD 16 billion in reduced consumer bills.

FIGURE 3.3: DATA EXCHANGE IN ASEAN COUNTRIES



[5] The Future of Cooling in Southeast Asia. IEA, October 2019. [Link]().

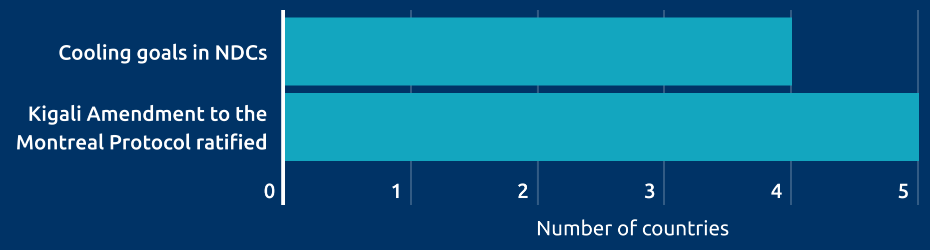
3.1.3 Climate change policies for cooling

Cooling and associated greenhouse gas (GHG) emissions have a substantial impact on countries' abilities to meet their climate change goals. Delivering sustainable solutions is also critical for increased adaptation and resilience to the effects of climate change, which can be included in NDCs. From a mitigation perspective, cooling appliances are responsible for the emission of GHGs both indirectly through the consumption of grid electricity and directly from the release of refrigerant gases with high GWP, such as hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs).

The Kigali Amendment to the Montreal Protocol, signed in October 2016, calls on countries to tackle both direct and indirect emissions from the cooling sector by drastically phasing down the use of HFCs as refrigerants while also improving the energy efficiency of cooling.

Among the Critical 9 countries, four refer to cooling in their updated NDCs submitted to the UN Framework Convention on Climate Change (UNFCCC): Bangladesh, China, India and Pakistan. The submission from Pakistan is the strongest; it lists the development of its NCAP as an adaptation action. Pakistan and Nigeria are working with the Clean Cooling Collaborative (CCC) to mainstream cooling in their NDC climate targets.[6] Five of the Critical 9 countries have ratified the Kigali Amendment – Bangladesh, China, India, Mozambique and Nigeria.

FIGURE 3.4: COOLING IN NATIONAL CLIMATE PLANNING IN THE CRITICAL 9 COUNTRIES



National Cooling Action Plans

In 2021, NCAPs were published for Ghana, Grenada, Kenya and Lebanon. Several other countries continue to make progress on their plans in partnership with technical assistance from UNDP, UNEP, GIZ, CLASP, the UN Economic and Social Commission for Asia and the Pacific (ESCAP), and SEforALL. The Cool Coalition[7], with support from coalition partners, released a holistic methodology for [developing an NCAP](), which provides guidance on how to plan for and make sustainable cooling for all a reality. Of the Critical 9 countries, three have already adopted an NCAP (Bangladesh, China and India), while four more (Brazil, Indonesia, Nigeria and Pakistan) are in the process of developing one, and two have yet to do so (Mozambique and Sudan).

[6] https://coolcoalition.org/k-cep-supports-10-countries-to-enhance-ndcs-with-new-work-on-efficient-climate-friendly-cooling/

[7] The Cool Coalition is a global multi-stakeholder network that connects a wide range of key actors from government, cities, international organizations, business, finance, academia, and civil society groups to facilitate knowledge exchange, advocacy, and joint action towards a rapid global transition to efficient and climate-friendly cooling. The Cool Coalition is now working with over 100 partners, including 23 countries.

FIGURE 3.5: GLOBAL STATUS OF NATIONAL COOLING ACTION PLANS IN 2022

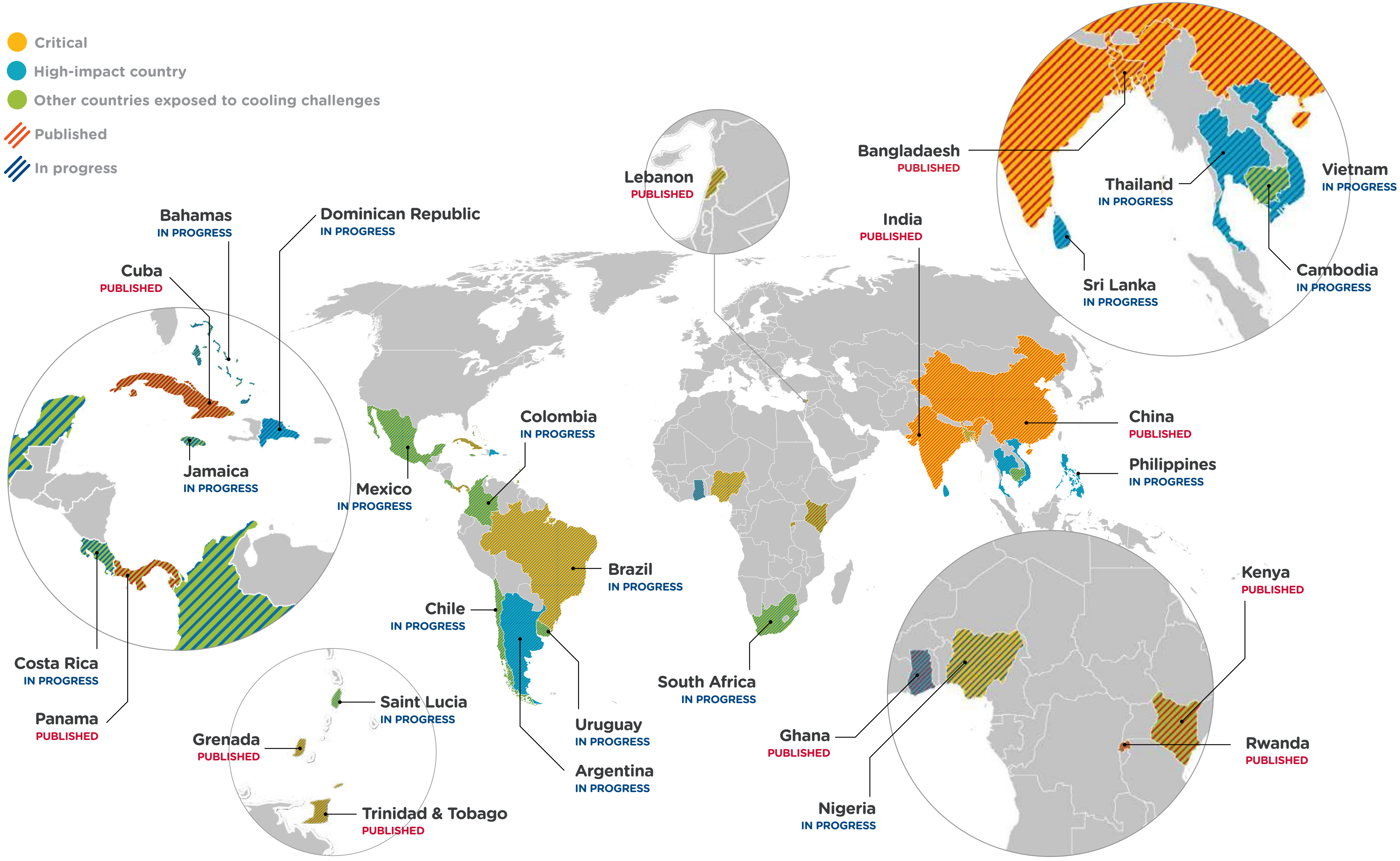


TABLE 3.2: SUSTAINABLE COOLING POLICY PROGRESS TRACKING

INDICATOR/CRITICAL 9 COUNTRY	BANGLADESH	BRAZIL	CHINA	INDIA	INDONESIA	MOZAMBIQUE	NIGERIA	PAKISTAN	SUDAN
What is the status of the NCAP? (not planned, under development, published)	Adopted	Under develop-ment	Adopted	Adopted	Under development	Not under development	Under develop-ment	Not under develop-ment	Not under develop-ment
ACCESS TO COOLING POLICIES									
Does the NCAP consider improved access to cooling?	Unknown	Unknown	Yes	Yes	Yes	No	Unknown	No	No
Is cooling demand considered in electrification planning?	Yes	No	Unknown	Unknown	No	Unknown	No	No	Unknown
Are there government mechanisms for off-grid ACs and fans?	Unknown	No	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Is the ownership rate of ACs and fans available? (through the national survey)	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No
Are there financial incentives for the purchase of efficient ACs and fans?	Unknown	No	Unknown	Unknown	Yes	Unknown	Unknown	Unknown	Unknown
Is passive cooling recognized in the national building code or other national strategy or policy?	Yes	Unknown	Partially	Yes	Partially	No	Yes	Unknown	No
Are there government mechanisms for off-grid refrigerators?	No	No	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Is the ownership rate of refrigerators available? (through the national survey)	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No
Are there financial mechanisms for affordable refrigerators?	Unknown	Yes	Yes	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Are agricultural cold chains recognized in a national strategy or implementation policy?	Unknown	Unknown	Yes	Yes	Unknown	Unknown	Partially	Partially	Partially
Is there an assessment of vaccine cold chain infrastructure?	Partially	Unknown	Yes	Yes	Yes	Yes	Partially	Partially	Partially

INDICATOR/CRITICAL 9 COUNTRY	BANGLADESH	BRAZIL	CHINA	INDIA	INDONESIA	MOZAMBIQUE	NIGERIA	PAKISTAN	SUDAN
ENERGY-EFFICIENCY POLICIES									
Are mechanisms for energy-services agreements (pay-for-performance contracts) available in the residential and commercial services and industrial sector?	No	Partially	Partially	Yes	No	No	Partially	No	No
Are there MEPS for ACs?	Yes	Yes	Yes	Yes	Yes	No	Yes	Partially	No
Are there MEPS for fans?	Yes	Yes	Yes	Yes	Yes	No	No	Partially	No
Is there import control regulation for ACs and fans?	No	No	Unknown	No	Unknown	Unknown	Unknown	Unknown	Unknown
Are there mandatory labels for ACs and fans?	Yes	Yes	Yes	No	Yes	No	No	No	No
Are there voluntary labels for ACs and fans?	No	No	No	Yes	No	No	Partially	Yes	No
Are there energy-efficiency codes for new residential or commercial buildings?	Yes	Yes	Yes	Yes	Partially	No	Yes	No	No
Are there energy-efficiency codes for renovated residential or commercial buildings?	Yes	Yes	Yes	No	No	No	No	No	No
Is the energy building code mandatory? (residential/commercial, new/existing buildings)	Yes	No	Yes	Partially	No	No	No	No	No
Are there financial incentives for efficient cooling in buildings?	Yes	Partially	Yes	Yes	Yes	No	No	No	No
Are there non-financial incentives for efficient cooling in buildings?	Unknown	Unknown	Unknown	Partially	Unknown	Unknown	Unknown	Unknown	Unknown
Are there MEPS for refrigerators?	Yes	Yes	Yes	Yes	Yes	No	No	Partially	No
Is there import control regulation for refrigerators?	No	No	Unknown	No	No	Unknown	Unknown	Unknown	Unknown
Are there mandatory labels for refrigerators?	Yes	Yes	Yes	Yes	Yes	No	No	No	No

INDICATOR/CRITICAL 9 COUNTRY	BANGLADESH	BRAZIL	CHINA	INDIA	INDONESIA	MOZAMBIQUE	NIGERIA	PAKISTAN	SUDAN
Are there voluntary labels for refrigerators?	No	No	No	No	No	No	Yes	No	No
CLIMATE CHANGES POLICIES									
Does the country have cooling goals in its NDC?	Partially	No	Partially	Partially	No	No	No	Yes	No
Has the country ratified the Kigali Amendment?	Yes	No	Yes	Yes	No	Yes	Yes	No	No

Note: 1) The Policy Tracker only maps policies in force (except for NCAP); 2) *Partially* refers to the existence of only one of the elements assessed in the policy (e.g., one type of product covered in the policy or only one sector targeted). For example, China has the largest ESCO market[8] but it does not target the residential sector,[9] hence it is rated as *Partially*; 3) The full policy tracking database contains additional information by policy.

[8] Evolving Energy Service Companies in China. IEA, August 2021. Link.

[9] Regulatory Indicators for Sustainable Energy. ESMAP. Link.

3.2 Sustainable Cooling Financial Flows

Finance for access to cooling is characterized by a diverse set of cooling needs that can be met with finance from an equally diverse set of financial sources or instruments. For example, cooling needs related to health services could be met by finance targeted at improved health care, cooling needs for agriculture could be met by finance for nutrition or agriculture business development, and cooling needs for human comfort could be met by finance for building or community development. The range of financial flows can be delivered through public procurement, grants, subsidies or commercial financing depending on the scale of investment and appetite for risk or sustainability of the business model for sustainable cooling. Over time, the types of instruments used to deliver on cooling needs will also change, as technologies and business models mature.

Knowledge briefs have been developed on the challenges, barriers and opportunities related to financing access to cooling, as well as the potential for a framework for tracking access to cooling finance. **Broadly speaking, access to cooling finance can be understood as public and private finance that supports enhanced affordability of — and access to — sustainable cooling solutions that support the cooling needs for food, nutrition and agriculture; health services; and human comfort and safety.** But the appropriateness of access to cooling finance and the instruments used will vary according to local conditions, including public resources, poverty levels and tiers of energy access, among others. Examples of finance that support access to cooling can be seen in table 3.3.

TABLE 3.3: INDICATIVE EXAMPLE FINANCE FLOWS TRACKED FOR SUSTAINABLE COOLING AND ACCESS TO COOLING

INSTITUTION	LEAD PARTNER(S)	FINANCE	FOCUS OR SECTOR
Cooling Facility	World Bank and GCF	$157 million, plus $722 million in leverage	Climate change mitigation and adaptation
NDC Facility	CCC, implementing partners	$12 million	Climate change – NDC focus
World Bank ESMAP Efficient and Clean Cooling Program	World Bank ESMAP	$15 million	Technical assistance, awareness raising, knowledge creation
ACES	U4E, Government of Rwanda, and University of Birmingham, UK	$6.8 million +	Technology, business models, and services to expand access to cooling in Africa
CaaS Alliance	BASE	~$50 million in assets under a CaaS model (estimate)	Technology and business models
Climate-friendly agricultural cold chains in India	UNEP, CCC, AEEE, EESL	$50 million mobilization target	Agricultural cold chains
Global Cooling Prize	Rocky Mountain Institute	Up to $3 million	Prize for sustainable air conditioner technology demonstration
Million Cool Roofs Challenge	Global Cool Cities Alliance (GCCA), CCC, SEforALL	$2 million	Prize for cool roof demonstration

International financial institutions and climate funds have a long history of financing cooling-efficiency projects in buildings, including for example through the International Finance Corporation's EDGE programme, and through financing from the Climate Investment Fund and the Global Environment Facility (GEF).

In 2021 however, there was a shift beyond projects focused on efficient space cooling, with a **significant amount of international climate finance mobilized for access to cooling.** In October 2021, the Green Climate Fund (GCF) approved a World Bank Cooling Facility with USD 157 million in direct GCF financing, which will be leveraging USD 722 million in World Bank co-financing. The facility will be administered by the World Bank and support projects in nine countries across the health, agriculture and space cooling sectors: Bangladesh, El Salvador, Kenya, Malawi, North Macedonia, Panama, Sao Tome and Principe, Somalia and Sri Lanka. The facility recognizes the wide range of cooling needs and priorities that come with a diverse set of challenges and solutions. In addition to being the largest mobilization of public financing dedicated to sustainable cooling solutions, the Cooling Facility is notable in that it explicitly aims to **support both climate-change adaptation and mitigation, expecting to avoid over 16Mt CO2e and reach over 21 million beneficiaries.** It thus supports the GCF goal of using 50 percent of its overall financing commitment to adaptation, but also serves to display how climate funds can use adaptation financing to support access to cooling. The facility will operate on the basis of a **Gender Action Plan** that ensures the finance is gender-responsive, aligns with and leverages existing World Bank gender strategies, and seeks to enhance the knowledge base on gender issues associated with access to sustainable cooling.[10]

The availability of **technical assistance to improve investment environments** has grown significantly. The philanthropic CCC made USD 12 million available to support the implementation of cooling commitments in NDCs, including in Nigeria, where U4E will support energy and cost savings through a revision of MEPS for air conditioners. The World Bank Energy Sector Management Assistance Program (ESMAP) Efficient and Clean Cooling programme also has USD 15 million available to raise awareness, build knowledge, and integrate efficient clean cooling into World Bank operations. The GCF has also supported the use of GCF Readiness Programme funds for strengthening governance and institutional planning, including through NCAPs. The development of such plans is now being supported in over 20 countries, including in Cambodia and Indonesia where the Cool Coalition's NCAP Methodology is being utilized to support sustainable cooling for all.

COUNTRY PLANS AND COMMITMENTS SIGNAL FUTURE FINANCIAL FLOW

NCAPs, as well as commitments in NDCs under the Paris Agreement, can serve as important market signals for investment. In follow-up to the India Cooling Action Plan, the World Bank commissioned a roadmap study that details the key policies, investment, and financing opportunities to support implementation of the India Cooling Action Plan.

[10] Consideration of funding proposals – addendum IXL funding proposal package for FP177. Green Climate Fund, 14 September 2021. Link. For Gender Action Plan, see Annex 8.

New initiatives and business models are also attracting more finance for access to sustainable cooling solutions. In Kigali, Rwanda, the Africa Centre of Excellence for Sustainable Cooling and Cold Chain (ACES) has received project financing of at least USD 6.8 million to support its mission of using training, policy, and technology expertise to demonstrate sustainable cooling pathways that meet Africa's social and economic cooling needs. The Basel Agency for Sustainable Energy (BASE) has estimated that USD 50 million worth of assets are under the Cooling as a Service (CaaS) servitization model, a figure that could grow to USD 300 million within the next four years.[11] In India, UNEP has partnered with the Alliance for an Energy Efficient Economy (AEEE) and Energy Efficiency Services Limited (EESL) to mobilize USD 50 million for sustainable cooling in agricultural cold chains through to the end of 2024.[12]

[11] Koegelenberg, Ilana, "Cooling in 2021: Growing Cooling-as-a-service Trend Expected to Accelerate," Ammonia21, 30 November 2020. Link.

[12] Reducing food loss and increasing farmers' income: Supporting efficient, climate-friendly agricultural cold chain in India. Clean Cooling Collaborative, 14 January 2021. Link.

THE SUCCESS OF PRIZES

Prize challenges have been a commonly used tool to incentivize technological and business model innovation since 2017. The USD 2 million Million Cool Roofs Challenge used base grants and a cash prize to support cool roof installations and the development of supply chains in several high-impact countries for access to cooling. The USD 3 million Global Cooling Prize similarly awarded prizes to manufacturers of air conditioners able to demonstrate a unit with five-times lower climate impact than baseline units at no more than two-times the cost. Under the Efficiency for Access Initiative, the Global LEAP Awards continue to drive innovation in off-grid cooling, including awards for off-grid refrigeration and cold chain, and the USD 3 million Research and Development Fund has supported the development and trial of new technologies and approaches that make efficient cooling more accessible in weak- or off-grid areas.

Driven in part by the emissions reduction potential, a significant amount of funding for technical assistance for cooling has supported MEPS for air conditioners. Broadening this type of assistance to include domestic refrigeration and the meaningful implementation of passive cooling into building codes for example can support additional investment and may be attractive to governments based on the immediate development and adaptation benefits they can provide. Additionally, the private sector remains an active investor in cooling solutions and due to the sheer scale of the issue will be central to delivering sustainable cooling for all, but the scale of the investment remains difficult to track.

Do you have data on access to cooling finance or details on specific projects that you would like to share or profile? SEforALL would like to learn more. Please email us at coolingforall@seforall.org.

3.3 Sustainable Cooling Community of Practice

Since the signing of the Kigali Amendment to the Montreal Protocol in October 2016, the number of initiatives concentrating on delivering sustainable cooling has grown significantly. With that, a community of practice on the issue has grown, covering several different action areas across key themes that include global advocacy and coordination; finance, business and services; and data, among others. This growing landscape of collaboration demonstrates the importance of the issue but can also create challenges for new or outside actors looking to navigate the space.

Many initiatives that originated in 2017, including SEforALL's Cooling for All programme, were supported by the philanthropic Kigali Cooling Efficiency Program (now the CCC), which played a catalytic role with early grant funding across four action areas to create a community of practice for sustainable cooling. Today, the Clean Cooling Collaborative works to scale emissions reductions and improve access to clean cooling, focusing on China, India, Southeast Asia and the US.

Complementing the CCC, the Cool Coalition works as a global, multi-stakeholder network to connect a range of actors to facilitate knowledge exchange and coordinate advocacy on cooling as both a climate change and development issue. SEforALL's Cooling for

All programme supports this overall global mission, with a focus on providing the data, knowledge and policy support necessary to deliver access to sustainable cooling in service of the SDGs.

In addition to early philanthropic capital, several actors are supporting public finance commitments to sustainable cooling, including through climate funds. This includes the World Bank ESMAP, which mobilized significant investment for Clean Cooling through the GCF, as well as bilateral donors such as the UK. The GCF has also supported the use of its national readiness funds for project preparation activities related to cooling, such as NCAPs.

Several multilateral and international organizations provide policy support and technical assistance to governments in support of public finance commitments. These include UNDP, UNEP the World Bank, CLASP and SEforALL among others. Organizations such as BASE and ACES provide similar, targeted support on business models and services, with BASE supporting CaaS and ACES promoting increased updates of sustainable solutions through education and training.

The initiatives discussed represent only a snapshot of the overall landscape of collaboration on sustainable cooling, with the number of initiatives constantly growing.

For more information, we invite you to reach out to the Cooling for All programme at SEforALL at coolingforall@seforall.org and explore the range of partners working with the Cool Coalition.

CHILLING PROSPECTS

CHAPTER FOUR

Reflecting on Five Years of the Kigali Amendment: Cooling for All Partner Stories

Introduction

The Kigali Amendment to the Montreal Protocol was signed in late 2016, with countries committing to cut the production of hydrofluorocarbons, powerful greenhouse gases typically used as refrigerants, by more than 80 percent over the next 30 years. The Amendment offered a historic opportunity to link its implementation with the improvement of energy efficiency in active cooling technologies, and to use holistic strategies to deliver on the cooling needs of vulnerable populations while reducing the overall energy demand needed for cooling. Since 2016, a growing number of initiatives have put these words to action, in support of the Kigali Amendment, the Paris Agreement on Climate Change, and the Sustainable Development Goals.

This includes the SEforALL Cooling for All programme, begun in 2017 with the support of the Kigali Cooling Efficiency Program (now Clean Cooling Collaborative). Since 2017, the Cooling for All programme has advocated for greater action on sustainable cooling and developed evidence, policy, and tools to make that action possible. This chapter profiles several interventions in action across the themes of Global Voices, Food, Nutrition, and Agriculture, Health Services, Human Comfort and Safety, Finance, and Regional Perspectives.

Each story provides insight on the impact of their work, as well as a vision for success in 2025, halfway through the decade of action for the Sustainable Development Goals and a critical milestone for the Paris Agreement on Climate Change.

GLOBAL VOICES

Clean Cooling Collaborative (formerly K-CEP): Catalytic finance for energy-efficient, climate-friendly cooling for all in 2050

In 2016, 17 leading climate foundations and individual donors came together ahead of the Montreal Protocol meeting in Kigali, Rwanda, and pledged more than USD 50 million to create the largest-ever fund of its kind for action on energy-efficient, climate-friendly cooling. The following spring, the Kigali Cooling Efficiency Program (K-CEP) was established.

K-CEP was charged with strategically programming the funds to advance cooling appliance efficiency reforms alongside efforts to support the implementation of the global phasedown of hydrofluorocarbons (HFCs) under the Kigali Amendment to the Montreal Protocol. If fully implemented over the next few decades, the Kigali Amendment has the potential to avoid up to 0.4°C of global warming by the end of the century, with the enhanced energy efficiency of cooling doubling those climate benefits. Action on energy-efficient, climate-friendly cooling has the potential to significantly boost global climate action efforts.

K-CEP aimed to create meaningful impact and catalyze transformation within the cooling sector through work on institutional strengthening for efficiency; policies, standards, and programmes; finance; and increasing access to cooling.

During the first four years of the programme, K-CEP granted USD 50 million to 54 partner organizations for projects in 57 countries. This work not only produced quantifiable results but created the infrastructure and momentum necessary for continued impact within the cooling sector.

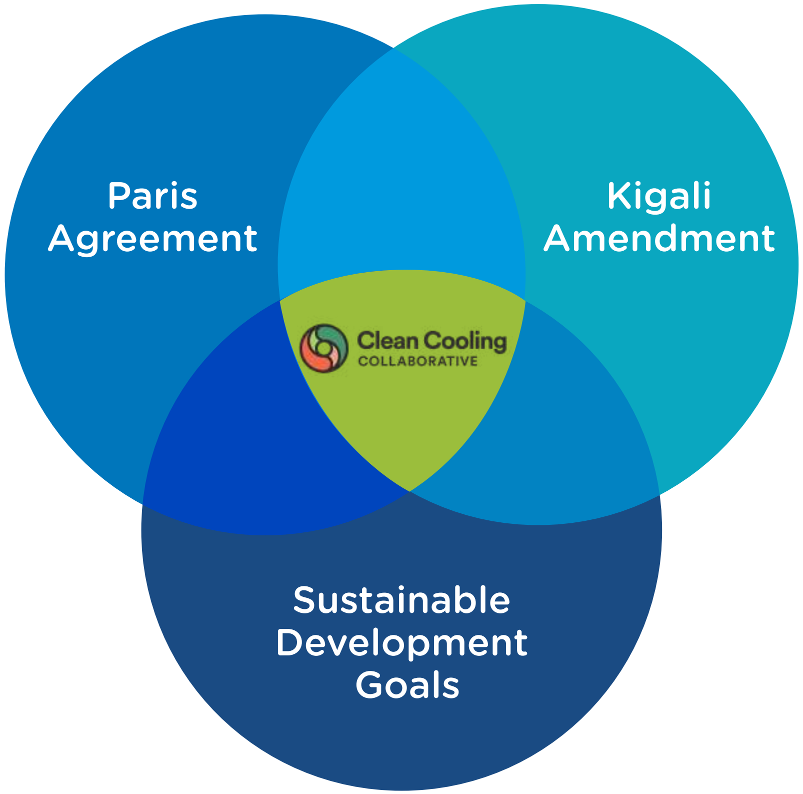
In terms of numbers, K-CEP supported the proposal, adoption, or implementation of 21 cooling appliance standards and labelling programmes around the world; the publication of nine National Cooling Plans; the development of three model regulation guidelines; and the mobilization of USD 600 million in investment. It helped with the formation of the Cool Coalition, which works to mobilize governments, industry, financial institutions, and businesses to act on cooling. It also enhanced its cooling knowledge base, built networks to power collaboration, and led a range of influential initiatives and partnerships.

Based on analysis from the International Energy Agency (IEA), it is estimated that K-CEP's activities, primarily the development of cooling efficiency policies and plans, will prevent the emission of 4.2 gigatons of carbon dioxide (GtCO2) by 2050.

Placing cooling on the global agenda

While it is easy to focus on the metrics, it is also important to consider the broader impact that K-CEP's work has had so far. In addition to securing sizable greenhouse gas emissions reductions, K-CEP has helped place cooling on the global agenda. It has brought attention to an issue that was often overlooked in terms of both its human impact and mitigation potential and raised the alarm on the dangerous feedback loop that today's conventional cooling can create, in which the very thing we need to keep us cool in an ever-warming world is significantly contributing to the heating up of the planet.

K-CEP's work on cooling is linked to several international agreements, namely the Kigali Amendment through supporting the transition to climate-friendly refrigerants, the Paris Agreement through work on energy efficiency and its associated emissions reductions, and numerous Sustainable Development Goals (SDGs), including climate action (SDG13), sustainable cities and communities (SDG11), zero hunger (SDG2), and good health and well-being (SDG3), to name a few.



The Clean Cooling Collaborative's work at the intersection of Paris Agreement, Kigali Amendment and SDGs

Building on the lessons learned during the programme's first four years, and in response to the changing global context, K-CEP has recently reinvented itself as the Clean Cooling Collaborative and shifted the focus of its work to maximize its impact over the coming years. While it will continue to make grants available worldwide, emphasis will be placed on the four regions with the greatest contribution to cooling sector emissions over the next 30 years: China, India, Southeast Asia and the United States. Energy efficiency will remain a central focus of its work, but it is expanding its programme to include work on supporting the transition to climate-friendly refrigerants, as well as passive cooling solutions and other issues like cold chains and demand response.

Providing access to cooling for all in a warming world

Through this work, the Clean Cooling Collaborative hopes to continue to improve cooling by reducing (or avoiding) the need for mechanical cooling through improved building design and by optimizing mechanical cooling so that when it is necessary, it uses climate-friendly refrigerants and significantly less energy. It also wants to increase access to cooling, which is not only important for ensuring human comfort, productivity, and resilience, but also necessary to improve food systems by reducing food waste, improving farmers' livelihoods, and enhancing nutrition.

With a goal of delivering energy-efficient, climate-friendly cooling for all for 2050, the Clean Cooling Collaborative is committed to securing the necessary transformation within the sector to provide people with access to the cooling they need in a rapidly warming world, in a way that minimizes energy use and greenhouse gas emissions in the most cost-effective way possible.

GLOBAL VOICES

Cool Coalition: The role of National Cooling Action Plans in delivering the global environment agenda

Increasing temperatures, growing economies, and more frequent heat waves and extreme weather events across the globe are resulting in a growing demand for cooling services.

In recent years, the issue of promoting sustainable and affordable access to cooling has emerged as an area of focus for governments, the health and food industry, real estate and technology providers, and financial institutions. Cooling services are essential to provide human comfort and productivity and ensure the safety of foods, medicine and vaccines, but can have negative environmental and economic impacts. Cooling is currently responsible for more than 7 percent of GHG emissions, and this figure is projected to double by 2050 if left unmanaged. Given the adverse impact of cooling on greenhouse gas (GHG) emissions and climate change, accelerated global efforts on policy, technology and finance availability for sustainable cooling have now become inevitable. Climate-friendly cooling could cut 8 years' worth of global emissions by 2050.

Current global status

Since the inception of the Kigali Amendment, the need for holistic and synergistic actions on achieving the Sustainable Development Goals (SDGs), Nationally Determined Contributions (NDCs) and Kigali Amendment targets has been witnessed globally. National Cooling Action Plans (NCAPs), global policy best practice, have gained prominence among countries beginning to develop long-term policy strategies. Starting in 2018 several countries opted to develop an NCAP with technical support from specialized agencies and address the cross-cutting nature of cooling, to bring stakeholders from government, industry and academia to the table, discuss needs and possible solutions, and translate this into a document that would provide a roadmap for action.

To accelerate global efforts, in 2020 the Cool Coalition brought together several of these NCAP pioneers and members and developed a guiding framework and holistic but modular methodology for the development of NCAPs that cover cooling comprehensively, including various sectors and end uses, and both met and unmet cooling needs. Currently, over 30 NCAPs are at various stages of development. Several countries, including Cambodia, Indonesia and Pakistan, are piloting the Cool Coalition methodology to develop their plans, and others have leveraged the methodology to strengthen their ongoing work.

Cool Coalition together with its partners organized a series of workshops between June and September 2021 to launch the NCAP Methodology, capture experiences and lessons learned from leading countries, and build capacity among national policymakers and stakeholders on developing and implementing NCAPs in various regions of the world. Some examples are:

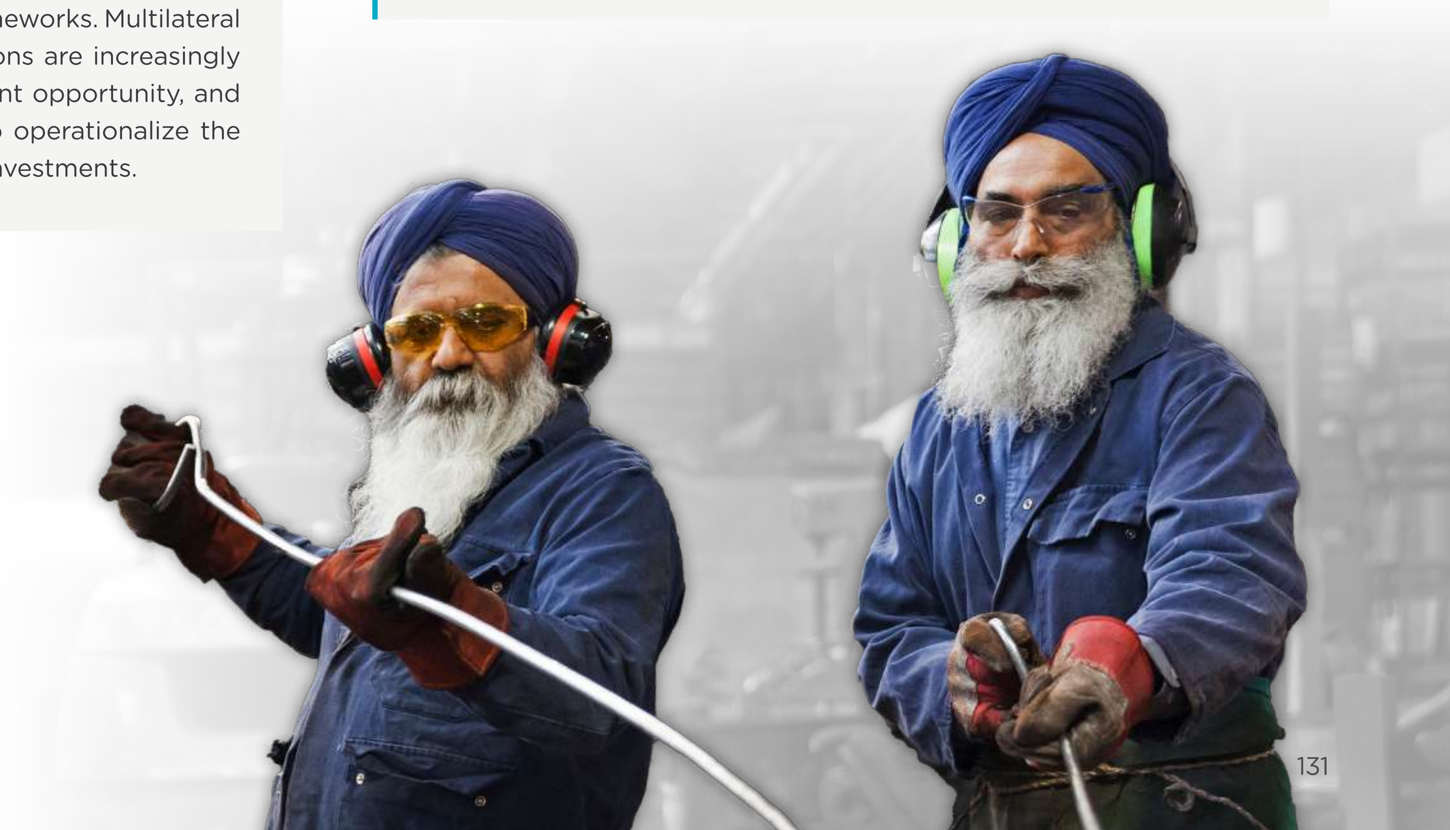
INDIA

The India Cooling Action Plan (ICAP) was among the first NCAPs launched in March 2019, developed by the Ministry of Environment, Forest and Climate Change (MoEFCC). The ICAP presents a 20-year outlook on how cooling demand in India will evolve in priority-demand sectors, and outlines strategies and actions that promote sustainable and smart cooling practices across the nation while mitigating adverse impacts. This landmark policy document demonstrates unprecedented inter-ministerial and cross-sectoral collaboration in identifying ambitious goals and laying out actionable pathways.

The government has established an implementation framework through inter-ministerial and cross-sectoral working groups by aligning the plan with sectoral priorities and existing policy frameworks. Multilateral development organizations and financial institutions are increasingly viewing cooling through the ICAP as an investment opportunity, and the World Bank Group has conducted a study to operationalize the implementation of the ICAP through multilateral investments.

PANAMA

Unlike most NCAPs, Panama's NCAP falls under the Ministry of Health. The Panama Cooling Plan (PCP) was developed by three key government entities on cooling: the Ministry of Health, the Ministry of Environment and the National Secretariat of Energy and was supported by the UNDP. The PCP emphasizes the sustainability of the transition process and the importance of the participation of the private sector and the general public, and places special emphasis on women and the needs of the most vulnerable. The plan is helping the government to align policies and programmes, identify synergies related to climate change, environment and health, and transition to climate-friendly refrigerants.



RWANDA

Rwanda was a pioneer in the development of its NCAP four years ago and now has ambitious cooling targets to reduce GHG emissions to 38 percent, rigorous energy-efficiency regulations and, together with the UK government, is developing the Africa Centre of Excellence for Sustainable Cooling and Cold-Chain (ACES). Its main objective is to address the complex and cross-cutting nature of climate-friendly cooling and incorporate the agriculture, health, industry, and building and construction sectors, both public and private. The NCAP serves as a call to sustained action with strategies that can be built upon over time. It is continuously strengthened and has a built-in ecosystem of multi-sector collaboration. Rwanda has a long-term vision to expand and collaborate regionally and internationally and is developing funding schemes to create access to sustainable cooling solutions and products.

CAMBODIA

The Government of Cambodia, through the Ministry of Environment's National Ozone Unit and its Department on Climate Change, and in collaboration with six other ministries, has prepared a comprehensive NCAP in partnership with the UN Environment Programme (UNEP) Cool Coalition and the Economic and Social Commission for Asia and the Pacific (ESCAP). It has included comprehensive cooling measures in its updated NDC and is now working towards the integration of passive cooling into its green building guidelines.

The aim of the NCAP is to build upon the existing work on the hydrochlorofluorocarbon (HCFC) phaseout and forthcoming Kigali Amendment implementation plans to integrate energy-efficiency and demand-reduction measures and, in doing so, accelerate refrigerant transition and maximize GHG emission reduction benefits. The development of the NCAP has helped the Government of Cambodia unify information on multiple cooling sectors, analyze potential economic, energy and GHG savings and identify pathways to integrate comprehensive action to address its current and future cooling demands.

Way forward and call for action

NCAPs have been recognized by countries, partners, the Technical and Economic Assessment Panel (TEAP) and the UN alike as key to linking efficiency and the refrigerant transition and maximizing climate benefits.

NCAPs are an important first step to establish frameworks and catalyze integrated and comprehensive action on cooling and cold chains. They can be used as a long-term strategy to achieve NDC targets and develop and deploy Kigali Amendment implementation plans. NCAPs have also helped countries attract finance for implementation.

However, the development of NCAPs requires resources. To date, these resources have been largely provided by the Clean Cooling Collaborative (formerly the Kigali Cooling Efficiency Program (K-CEP)). Green Climate Funds (GCF) has indicated that countries can request its readiness funds to develop NCAPs, and several other development banks have also signalled their interest in supporting countries.

The Cool Coalition finance working group will also explore opportunities to support member countries who express an interest in developing NCAPs. However, given the importance of NCAPs in accelerating the refrigerant transition, it is hoped that funds could also be made available under the Multilateral Fund for the Implementation of the Montreal Protocol (MLF).

Meet our Global Panel on Access to Cooling member from the Cool Coalition

Mark Radka
Chief of Energy and Climate Branch Organization, UNEP

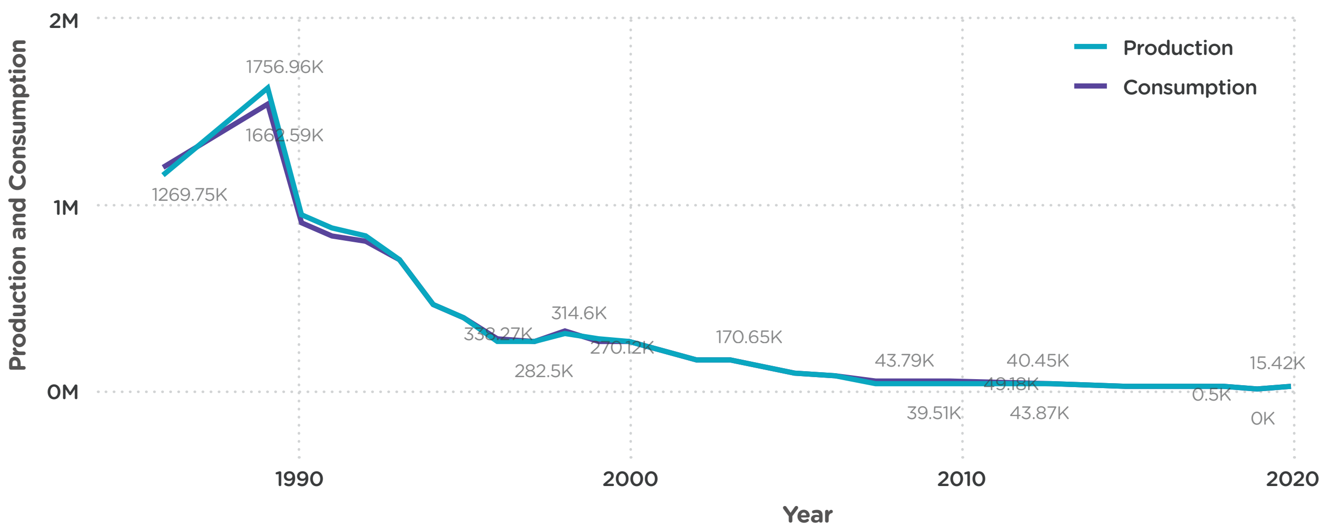
GLOBAL VOICES

Ozone Secretariat: Ozone Treaties – a global partnership for more sustainable cooling

Cooling covers a broad segment of the economy that uses refrigerants, many of which are controlled by the Montreal Protocol on Substances that Deplete the Ozone Layer.[1] It is part of more than 200 economic sectors that include comfort cooling, cold chain for agri-food systems and vaccines, and foam manufacturing. As such, the impact from the work undertaken by Parties under the Montreal Protocol is cross-cutting and contributes to almost all Sustainable Development Goals (SDGs) either directly or indirectly.

With the projected increase in global demand for cooling,[2] we need to move this sector onto a more sustainable path. Given its universal ratification and the concrete results it has achieved to date, the Montreal Protocol provides a well-established framework for transition to lower global-warming alternatives with tangible improvements in energy efficiency, safety and affordability of cooling equipment.

The Ozone Secretariat and the UN Environment Programme (UNEP) have developed data hubs (i.e., the data centre of the Ozone Secretariat and the World Environment Situation Room of UNEP) with interactive features for the analysis of the data reported by the Parties to the Protocol. These data show that the global implementation of the Montreal Protocol has led to the phaseout of 99 percent of ozone-depleting substances (ODS), or 1.8 million ozone depletion potential (ODP) tonnes, globally. The remaining 1 percent (approximately 200,000–300,000 metric tonnes) is largely hydrochlorofluorocarbons (HCFCs). A global phaseout of ODS is expected by 2030.



[1] The ozone layer filters out the sun's harmful ultraviolet radiation that can otherwise cause a higher incidence of skin cancer and damage land and marine ecosystems including the capacity of some to store carbon.

[2] The Future of Cooling, International Energy Agency, 2018

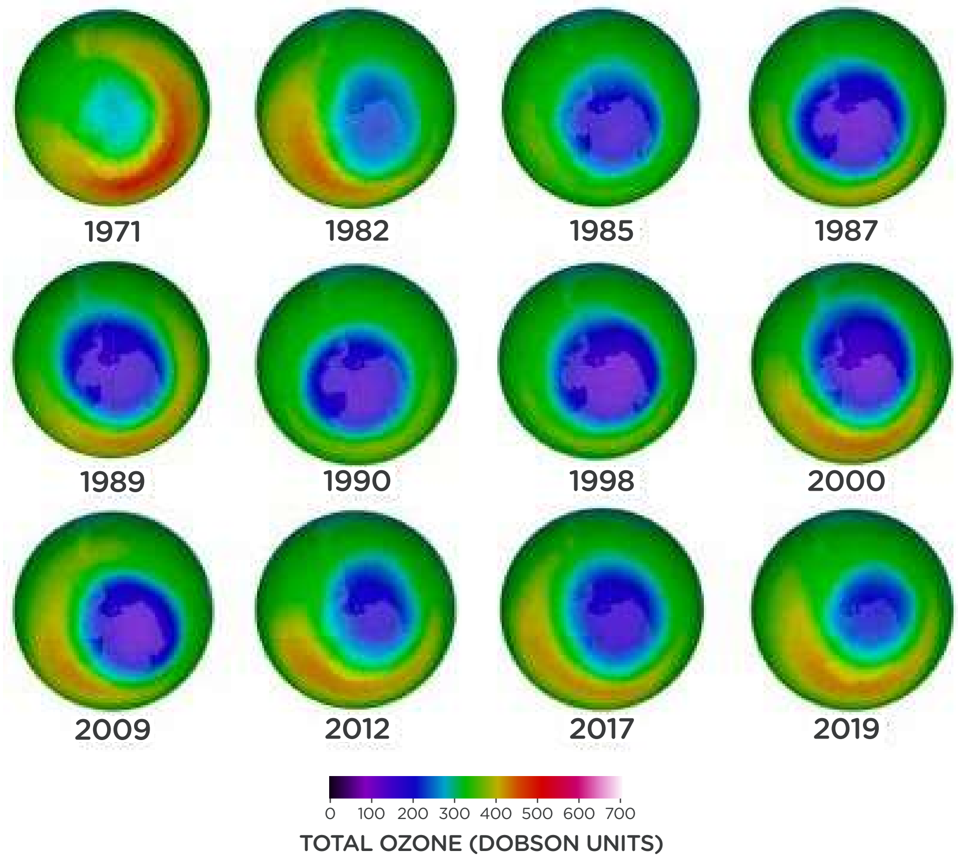
Given the high global warming potential of many ODS, it is estimated that without the Montreal Protocol atmospheric carbon dioxide concentrations would have increased by an additional 115–235 parts per million by the end of the century.[3] This would have translated into a **rise in global mean surface temperature of 0.5-1.0 °Celsius**. In addition, the implementation of the 2016 Kigali Amendment to the Montreal Protocol, which added 18 hydrofluorocarbons (HFCs) to the list of controlled substances, is projected to prevent up to 0.4 °Celsius of global warming by the end of this century. While HFCs do not destroy the ozone, they warm the climate with a potential far greater than that of carbon dioxide.

In 2020, based on the annual statistical data reported by Parties on their consumption and production of controlled substances, developing countries phased out 35 percent of HCFCs from their baselines set at the levels of 2009–2010 while developed countries reached the full phaseout. According to the 2018 scientific assessment of ozone depletion, undertaken by the Montreal Protocol's independent Scientific Assessment Panel, actions taken under the Montreal Protocol have led to long-term decreases in the atmospheric abundance of controlled ODS and the ongoing recovery of stratospheric ozone. Northern Hemisphere and mid-latitude ozone is expected to heal completely by the 2030s while Southern Hemisphere mid-latitude ozone is expected to do so in the 2050s. The Antarctic ozone hole is expected to close in the 2060s.

Moving towards zero ozone-depleting cooling

The Kigali Amendment has been ratified by 131 Parties to date. Since its entry into force three years ago, Parties to the Montreal Protocol have been busy meeting the prerequisites for its implementation such as extending the existing licensing systems for export and import of controlled substances to

ANTARCTIC TOTAL OZONE
(October monthly averages)



False colour view of total over the Antartic pole. The purple and blue colours are where there is the least ozone and the yellows and reds are where there is more ozone.

Source: NASA Ozone Watch

[3] Summary Update 2021 for Policymakers, UNEP, Environmental Effects Assessment Panel, 2021

cover HFCs, conducting situational analyses to estimate baselines for these substances (to be set at the level of 2020–2022 for developing countries) to measurably phase down their production and consumption, and implementing initial enabling activities and/or demonstration projects funded by grants from the Multilateral Fund for the Implementation of the Montreal Protocol. Parties to the Protocol are also encouraged to design and conduct their national phasedown programmes in coordination with other national priorities on climate change, energy efficiency and other relevant areas. The first milestone for most developing Parties under the Kigali Amendment is to freeze their production and consumption of controlled substances in the year 2024.

In its 2021 review of energy-efficient and low global-warming potential technologies, the Technology and Economic Assessment Panel of the Montreal Protocol indicated that the cooling sector consumed 20 percent of electricity produced globally in 2019, and the demand for refrigeration and air-conditioning units would increase significantly in the next few decades. If the rate of energy consumption by the cooling sector remains unabated and current refrigerants in the cooling system do not switch to lower global warming potential alternatives, the sector will contribute to global warming that surpasses the 1.5°C target of the Paris Agreement by 2030.

The review also identified a variety of existing best available technologies and policy solutions that need to be adopted and implemented urgently and at scale. Achieving the universal ratification of the Kigali Amendment will be an important opportunity for climate action. Full implementation of the commitments under the Amendment and the Montreal Protocol can help the world move towards zero ozone-depleting, low global-warming, safe and energy-efficient cooling. As the world slowly emerges from the pandemic, integration of considerations for more sustainable and affordable cooling into economic recovery packages will be essential for equitable, resilient and sustainable development.

Meet our Global Panel on Access to Cooling member from the Ozone Secretariat

Megumi Seki

Executive Secretary of the Ozone Secretariat

GLOBAL VOICES

SEforALL Cooling for All Programme: #ThisIsCool communications tool

#ThisIsCool is a communications tool that highlights the diversity of affordable, efficient and clean cooling solutions. #ThisIsCool messages showcase innovative solutions and link cooling to the achievement of the Sustainable Development Goals (SDGs). #ThisIsCool does this by elevating cooling as an issue of equity in a warming world, connecting youth with development partners, policymakers, industry and funders to advance commitments and invest in cooling solutions.

Programme at a glance

- Campaign launched in 2020
- #ThisIsCool posts from SEforALL account: 210
- #ThisIsCool engagements: 5,704
- #ThisIsCool impressions (across all social media channels): 5,704
- 53,301 followers on Twitter
- 45,332 followers on LinkedIn
- 4,190 followers on Instagram
- 1,010 followers on TikTok

Launched in July 2020, the first stages of the campaign reached more than 53,000 people on Twitter and 45,000 on LinkedIn, with more people engaging through SEforALL's partners. With the objective of raising awareness about cooling solutions, we call on followers and sustainable cooling solution providers to help spread the word about sustainable cooling solutions by using the Sustainable Cooling Solutions Toolkit and by sharing more stories.

At the end of 2021, the #ThisIscool campaign had an estimated timeline reach of 38.3 million and a #ThisIscool hashtag reach of 10.78 million. The microsite developed for the campaign was viewed over 23,000 times and more than 750 people downloaded the communications toolkit.

FOOD, NUTRITION & AGRICULTURE

CLASP: Making sustainable, affordable refrigeration a reality for all

Refrigerators have the potential to unlock an array of social and economic benefits for consumers living in off- and weak-grid areas. They contribute to many of the Sustainable Development Goals (SDGs) (Figure 1), from promoting good health and wellbeing (SDG3) to reducing inequalities (SDG10) as the domestic burden of food gathering and preparation usually falls on women and children. Refrigeration is also essential in hospitals and clinics – especially for vaccine storage – and enables income-generating activities for small businesses through the storage and sale of drinks and perishable items.

Despite their potential impact and high demand[1], off-grid refrigerator sales and market penetration rates remain low. In 2020, it was estimated that only 4 percent of rural households in Sub-Saharan Africa owned a refrigerator.[2] This is largely due to affordability – without financing, the cost of refrigerators can be two and a half times higher than the annual disposable income of the poorest

FIGURE 4.1: REFRIGERATOR INTERLINKAGES WITH THE SUSTAINABLE DEVELOPMENT GOALS (SDGs)

[1] In 2020, household refrigerators ranked fourth for perceived consumer demand and third for impact potential among other off-grid appliances in a sector survey.

[2] The State of the Off-Grid Appliance Market Report, Efficiency for Access Coalition, 2019

50 percent of off-grid households.[3] Power system, duties/taxes, and transport are significant cost drivers, accounting for more than half of the total cost to the end user.[4]

Compared to smaller household appliances, refrigerators are energy intensive and thus need a larger solar energy system to power them. Solar systems can account for approximately 75 to 83 percent of the total cost of an inefficient refrigerator.[5] Efficiency improvements are therefore key to unlocking improved affordability by reducing the up-front cost of solar energy systems. Efficient off-grid refrigerators also help curb greenhouse gas (GHG) emissions. One unpublished analysis from CLASP found that replacing inefficient diesel-powered refrigerators in Nigeria with highly efficient solar models could avoid 625,507 tons of carbon dioxide (CO2) emissions, equivalent to taking 136,035 cars off the road for a year.[6]

Expanding the market for efficient and affordable off-grid refrigerators to improve lives

In recent years, research and development (R&D) investments, donor-supported financing programmes, and business model innovations have all supported improvements in the price and efficiency of off-grid refrigerators and increased their uptake.

Financing programmes are bringing high-quality refrigerators to scale. An increasing number of programmes are providing support to help manufacturers finance high-performing refrigerators. For example, Global LEAP Results-Based Financing (Global LEAP+RBF)[7] is catalyzing the uptake of high-quality and efficient appliances by lowering the cost to procure large volumes of best-in-class products. These efforts have resulted in sales of over 5,100 high-quality off-grid refrigerators across East and West Africa, benefitting nearly 7,400 people living in off- and weak-grid areas.

Technology innovations are improving efficiency and price. Recent innovations in insulation, compressor efficiency, and better controllers are driving down prices and improving efficiency, with the average efficiency of off-grid refrigerators improving by 12 percent from 2017 to 2019.[8] These improvements may be due in large part to R&D efforts and technology innovations from leading refrigerator manufacturers, which are achieved in-house or with grants, such as the Efficiency for Access R&D Fund.

One example of a promising innovation in the sector is the use of Peltier cooling refrigerators, which operate with no compressor, meaning that there are no moving parts apart from the fan. One of the main benefits of this technology is lower manufacturing costs and therefore greater affordability due to the small number of parts. Without refrigerants or a compressor, Peltier cooling refrigerators are also easier to transport to end users.[9] Another innovation, digital inverter compressors, can increase refrigerator efficiency and operate on AC or DC power, making them viable for households in weak-grid areas.[10]

Refrigerators are creating new opportunities for small-business owners. 90 percent of customers who purchase a refrigerator through the Global LEAP+RBF programme use it at their workplace, primarily to sell cold beverages. After purchasing their refrigerator, users increased their daily incomes by two and a half times, on average. In a 2020 survey, 90 percent

[3] Appliance Data Trends, Efficiency for Access Coalition, 2021

[4] Use Cases and Cost Breakdown of Off-Grid Refrigeration Systems, Efficiency for Access Coalition, 2020

[5] Appliance Data Trends, Efficiency for Access Coalition, 2021

[6] Greenhouse Gases Equivalency Calculator, Environmental Protection Agency

[7] Global LEAP+RBF is a financing programme for Winners and Finalists of the Global LEAP Awards. Learn more about the Global LEAP Awards and Global LEAP+RBF here.

[8] Appliance Data Trends, Efficiency for Access Coalition, 2021

[9] Low-Energy Inclusive Appliance Technology Summaries, Efficiency for Access, 2021

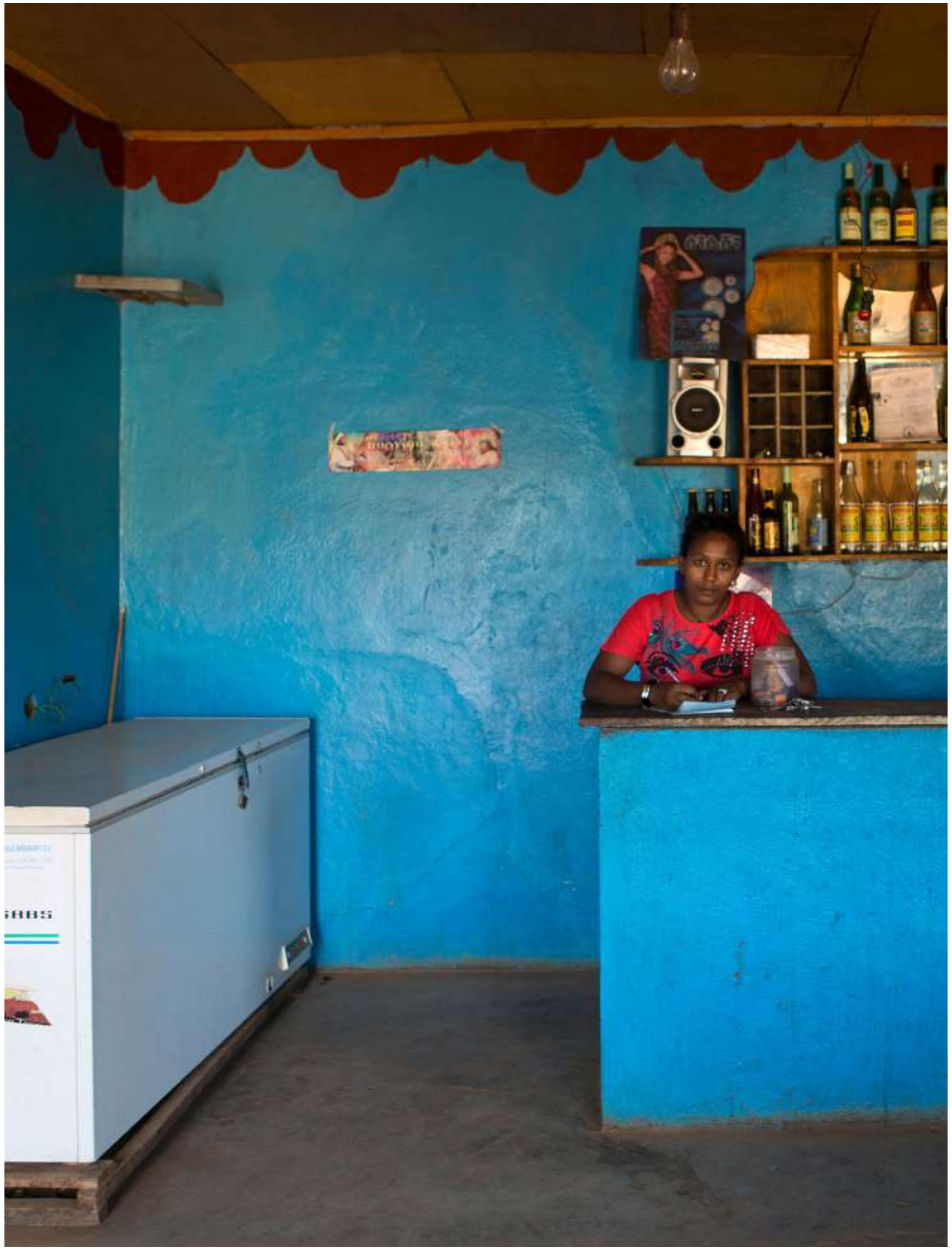
[10] Ibid.

of customers shared that their refrigerator had improved their quality of life, primarily due to improved income.[11] An M-KOPA survey found that small businesses with a refrigerator in rural Kenya increased their weekly income between USD 1 to USD 40 on average, and households saved an average of USD 4.82 per week from improved food storage and making fewer trips to the market. Beyond increased savings, respondents reported improved diets, lower stress, increased convenience, and time savings estimated at two hours weekly.[12]

What can be achieved through scale up by 2025

With greater affordability and increased efficiency, the cumulative global market potential for off-grid refrigerators is projected to grow by 10 percent each year, from USD 4.4 billion and 11 million households in 2018 to USD 8.7 billion and 23 million households by 2025. With these projections, an estimated 20 million people could gain first-time access to a refrigerator by 2025, resulting in over 250,000 new home-based jobs.[13] However, improvements in affordability, product quality, after-sales care, business models and consumer awareness will be critical to growing the off-grid refrigerator market over the next three years.

Scaling the off-grid refrigerator market would be transformational for people living in energy poverty, particularly women and girls. For example, M-KOPA found that 60 percent of refrigerator users stated that women benefitted the most from owning a refrigerator – these benefits included freeing up time



[11] These data are from an unpublished survey from CLASP and 60 Decibels that interviewed Global LEAP+RBF refrigerator customers.

[12] Innovation and product development: why some products take off and others don't, CDC Group, 2019

[13] These numbers were calculated using the Efficiency for Access Impact Assessment Framework and assume that there is one refrigerator per household for the 25 million households estimated to own a refrigerator by 2025. This number only includes domestic refrigerators; the impact potential would be much greater if refrigerators used for non-domestic businesses were included.

spent on household activities, saving from purchasing in bulk, reducing stress and creating small-business income generation.[14] Refrigerators can therefore promote gender equity at both business and household-use levels.

New types of refrigeration solutions are emerging to serve various market segments, including fisheries, dairy and smallholder agriculture. Off-grid cold chain units have the potential to increase farmers' profits by opening new markets for high-value crops and reducing food waste, enabling developing countries to raise food supply by 15 percent – about 250 million tons.[15]

As global temperatures rise and disproportionately affect people living in the developing world, cooling technologies such as refrigerators will be essential to health, survival and productivity. Off-grid refrigerators are on the cusp of transformational growth, with significant progress being made on affordability, accessibility and product design. In the coming years, further improvements in efficiency and price, among other factors, will be key to accelerating access to highly impactful refrigeration in off-grid communities.

Meet our Global Panel on Access to Cooling member from CLASP

Ana Maria Carreño
Senior Manager, CLASP

[14] Innovation and product development: why some products take off and others don't, CDC Group, 2019

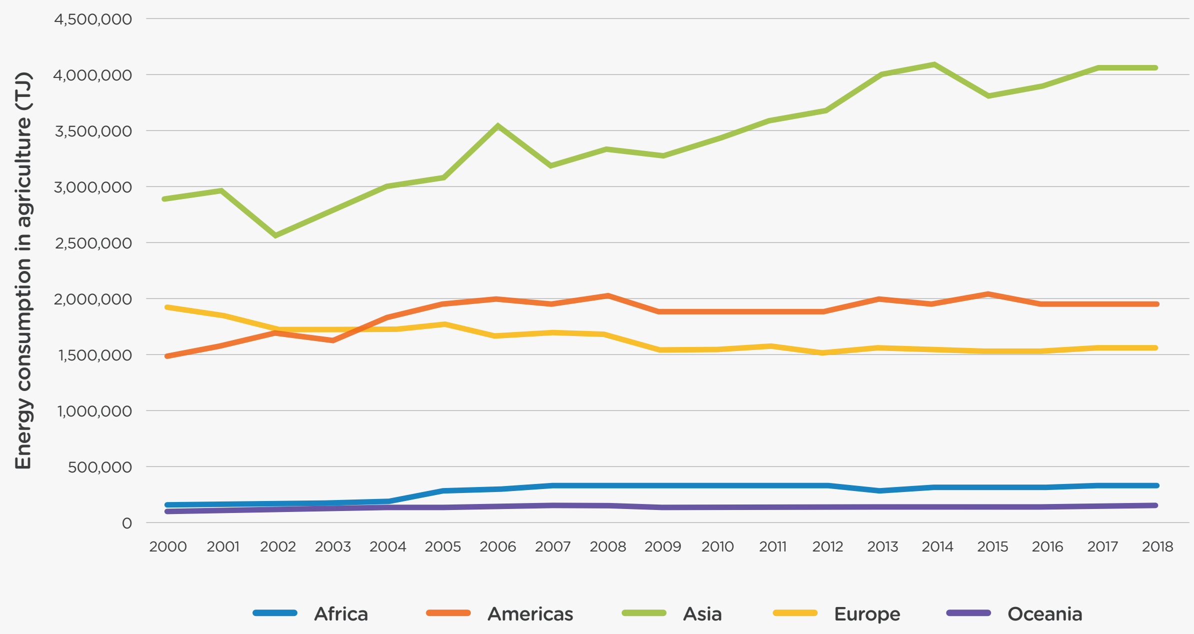
[15] The Role of Refrigerators in Worldwide Nutrition: 5th Informatory Note on Food and Refrigeration, IIR, 2009

FOOD, NUTRITION & AGRICULTURE

Food and Agricultural Organization of the United Nations (FAO): Promoting sustainable agricultural food chains through the Energy Smart Food programme

Energy is needed at all stages of the agri-food chain. The agri-food sector currently consumes 30 percent of the total energy demand globally, most of which is fossil fuel based. There are however differences in energy use patterns in the agri-food chain across regions. In developed countries, about a quarter of total energy is used in the production stage (crops, livestock and fisheries), 45 percent in food processing and distribution, and 30 percent in retail, preparation and cooking. In developing countries, a smaller share of energy is used in the production stage and a greater share for cooking.

FIGURE 4.2: ENERGY CONSUMPTION IN AGRI-FOOD SYSTEMS, BY REGION, 2000–2018



Source: FAOSTAT, 2021

While energy use in the agri-food chain increased by 20 percent between 2000 and 2018 globally, in Africa, it remained largely constant, accounting for only about 4 percent of global energy consumption (FAO, IRENA 2021). Limited energy access directly impacts local agri-food systems by reducing opportunities both to increase irrigation that would increase yields and to store food in temperature-controlled environments that would reduce food loss. This, in turn, limits food diversity.

While there is a need to increase access to energy to the agri-food chain in developing countries, following the conventional pathways of depending on fossil fuels will only exacerbate climate change. Renewable energy can be instrumental in increasing energy access in a way that minimizes greenhouse gas (GHG) emissions and it is becoming increasingly more affordable. The cost of electricity from solar PV and wind for instance decreased by 82 percent and 40 percent respectively between 2010 and 2019. (IRENA 2020).

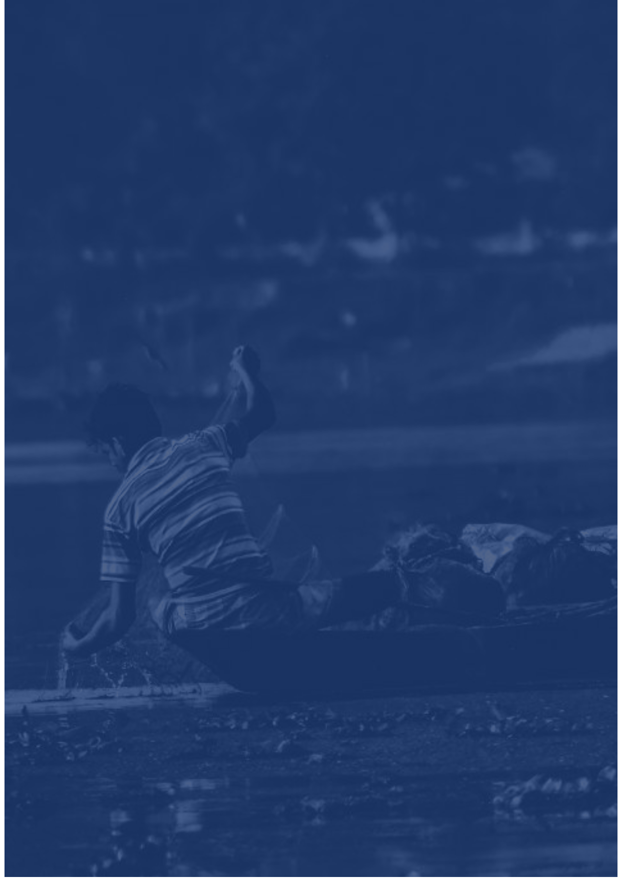
The Food and Agricultural Organization's (FAO's) Energy Smart Food (ESF) programme aims to increase access to sustainable energy in food systems through innovative, green energy solutions that encompass improved energy efficiency, the use of renewable energy, increased circularity through waste-to-energy along agri-food chains, and a water-energy-food nexus approach.

Meet our Cooling for All Advisor from the FAO

Manas Puri
Sustainable Energy in Agriculture Expert, FAO

FOOD, NUTRITION & AGRICULTURE

World Bank Group: Integration of inland waterways in the cold chain in West Bengal



West Bengal produces a lot of fruits, vegetables and fish, and has well-connected networks of highways and railways. However, transport accounts for 2.6 million tonnes of greenhouse gas (GHG) emissions in the state. In addition, inefficiencies and a lack of transport connectivity adversely affect the state's economy, increase congestion and contribute to post-harvest losses of temperature-sensitive goods. Waterways have the potential to support a multi-modal cold chain transportation network with reduced emissions, environmental impact, fuel usage and costs.

POTENTIAL OF INLAND WATERWAYS

Environmental impact	7 times less than road-ways
Carbon friendly mode of transport	For every tonne-km transported on water, the GHG emission is estimat-ed to be 50% of that by road
Most fuel-efficient mode of transport	105 tonne-km by with 1-litre fuel
Low maintenance cost	20% that of road
Low capital cost	5-10% to that of a 4-lane highway/railway

Source: World Bank Group

Improving the inland waterways infrastructure

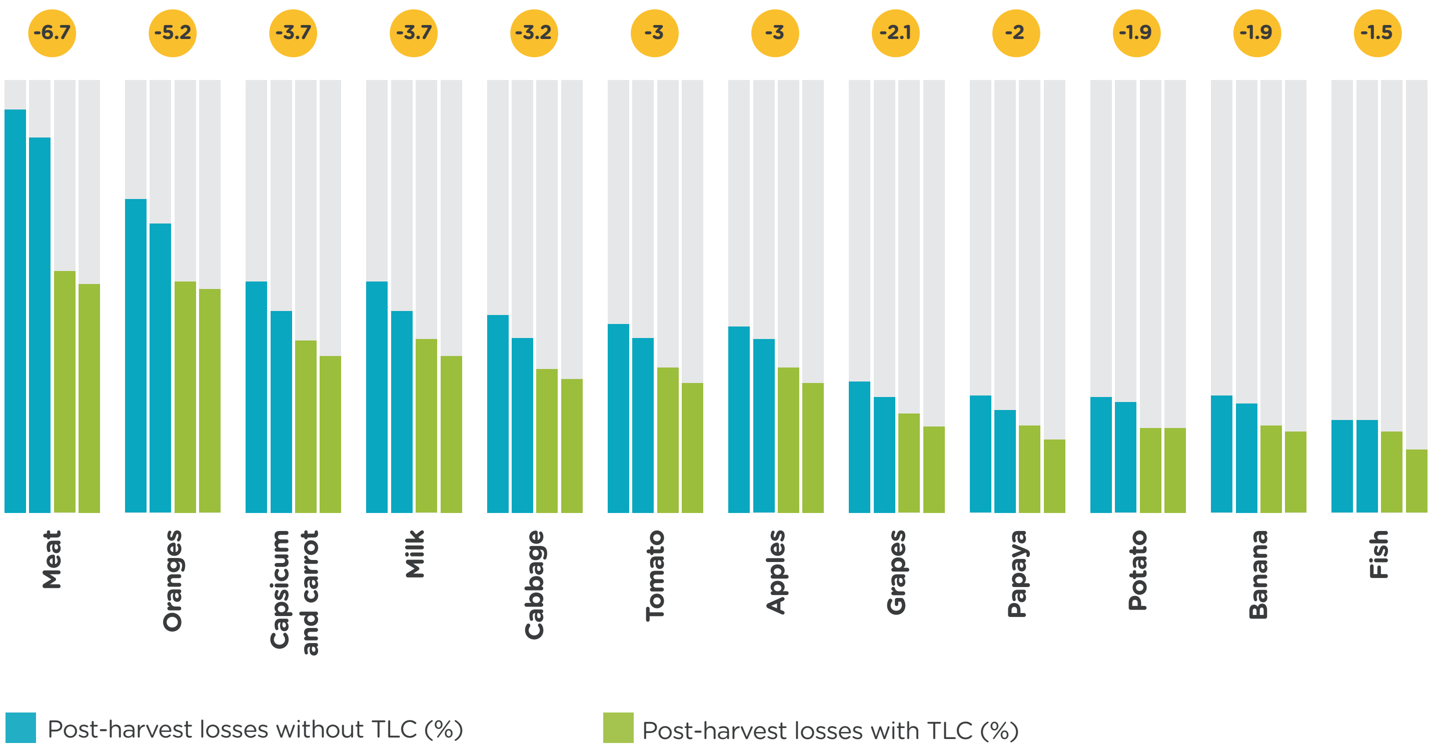
To address this, the Government of India, the Government of West Bengal and the World Bank signed a USD 105 million project to improve inland waterway (IW) infrastructure and spatial planning in Kolkata in January 2021. To complement this lending project, the World Bank with funding from the UK's Department for Environment, Food and Rural Affairs (DEFRA) contracted KPMG India and the International Institute of Refrigeration (IIR) to undertake a pilot study on IW integration in the West Bengal Cold Chain to reduce congestion, GHG emissions and hydrofluorocarbon (HFC) refrigerant usage.

The initial baseline assessment of the project reviewed the demand and emissions of temperature-sensitive goods such as fruits, vegetables and fish in West Bengal across the post-harvest, primary-transport, cold-storage and distribution segments of the cold chain. The study, conducted by KPMG India and IRR under the World Bank, found that in 2020, the total Temperature Controlled Logistics (TCL) demand was 6.28 million tonnes, accounting for 1.98 million MWh of energy consumption and over 620,000 tonnes of CO_2 emissions annually.

A key driver of the demand arises from the production and transportation of temperature-sensitive goods. About 65-70 percent of freight in India is transported by road and the transportation of fruits and vegetables to and from Kolkata wholesale markets and mandis primarily takes place in non-refrigerated trucks. This results in food spoiling, reduced shelf life and post-harvest losses to the tune of 10-15 percent. The global footprint of food loss and waste excluding emissions from land-use change is 3.3 gigatonnes of GHG, corresponding to about 7 percent of total GHG emissions. There is a need for a new cold chain infrastructure for most products.

An efficient, well connected cold chain in West Bengal has the potential to significantly reduce post-harvest losses

TLC: TEMPERATURE CONTROLLED LOGISTICS.



Source: World Bank Group

The Government of India has shown a keen interest in IWs as a means of diversifying and improving the transport modal mix, which could also reduce post-harvest losses while reducing the negative environmental impact and cost of meeting the cold chain demand. IW transport has an environmental impact which is seven times less than roadways, and for every tonne-Km transported on water, the GHG emission is estimated to be 50 percent of that by road. Additionally, IW is a fuel-efficient mode of transport (105 tonne/km with one litre of fuel), has a lower capital cost (about 5–10 percent of that of a four-lane highway/ railway), and maintenance costs 20 percent lower than roads. In order to understand the feasibility of transporting temperature-sensitive goods on waterways, the study looked at the potential impact of diverting traffic to IW.

Integrating inland waterways with RoRo cargo services

In 2026, there is the potential to divert around 30,556 tonnes of traffic to IW while around 233,409 tonnes could potentially be diverted via roll-on roll-off (RoRo) cargo service. In 2035, around 210,419 tonnes could be diverted to IW and around 1,084,346 tonnes could be diverted to RoRo. With the integration of IW and RoRo services, there is the potential for GHG emissions savings of around 10 percent and 27 percent in 2026 and 2035, respectively. In addition, with the adoption of newer technologies, fisheries could save up to 77 percent of their energy consumption by 2030 and fruits and vegetables could save up to 77 percent. Cold storage for potatoes could save up to 75 percent by shifting to improved technologies. The fruit and vegetable value chain could save about 38 percent in post-harvest refrigeration but could save up to 77 percent in transportation. The dairy value chain could save 83 percent of its energy demand by the end of 2030.

Overall, the integration of IW in sustainable cold chains is promising but requires context-specific evaluation. The study in West Bengal is expected to inform the financing of 'greener' vessels with energy-efficient cooling technologies that can have significant climate benefits. However, the refrigerant market is underdeveloped in India and West Bengal. Some cold chain facilities operate using R22 or R404A, which are higher Global Warming Potential (GWP) refrigerants. R22 will be banned from use in India in 2030.

Reaping climate and economic benefits

However, while refrigerants such as R717 with low GWP would be preferable, it is prohibited in the KMA following the 2011 ammonia gas leaks that had detrimental health and safety impacts. In addition, the initial findings of the assessment of the three pilot models (for potatoes, Tetra Pak milk and fisheries) noted that the longer travel time needed by IW may not be well suited for certain temperature-sensitive goods. Based on these results, by 2025 these barriers will need to be addressed to effectively divert temperature-sensitive goods to IW and reap the associated climate and economic benefits.

Meet our Global Panel on Access to Cooling member from the World Bank Group

Johannes Heister

Senior Environmental Specialist, World Bank

HEALTH SERVICES

Clinton Health Access Initiative: Expanding the vaccine cold chain in Kenya through innovative cooling solutions

The lack of reliable electricity at public health facilities in Kenya has been a significant challenge to expanding its vaccine cold chain. While residential energy access increased from 52 percent to 70 percent between 2016 and 2019, energy access at government-operated health facilities only grew by 1 percent from 69 percent to 70 percent in the five-year period 2016 to 2021.[1 2]

Historically, and in the absence of reliable electricity, absorption technology refrigerators have played a key role in expanding the cold chain. This cooling technology is intended to be mains powered with liquified petroleum gas (LPG) serving as a backup. However, in 2016, 13 percent of facilities relied entirely on LPG as a main source of power as they lacked access to any other form of electricity.[3] Despite effectively expanding the cold chain where it otherwise did not exist, LPG refrigerators proved to be environmentally damaging, expensive and unreliable.[4]

With an estimated monthly LPG consumption rate of 11.4 kg, these refrigerators consume approximately 123 tonnes of LPG in a single year and cost USD 422 per health facility.[5] They also have shorter life spans than optimal cold chain equipment (CCE) and are often responsible for vaccines freezing as they lack freeze-protection mechanisms. This contributes to a facility-based freeze excursion rate of 3.5 percent.[6]

Optimizing the cold chain with innovative cooling solutions

To overcome the challenge of a costly and environmentally damaging cold chain, the Ministry of Health (MoH) has set the ambitious goal of strengthening the vaccine supply chain by equipping all facilities with optimal CCE by 2026. Optimal CCE consists of cooling solutions that meet a standard of performance criteria set out in the World Health Organization's (WHO) Performance, Quality, and Safety Catalogue requirements that is referred to as platform-eligible CCE (in line with Gavi's Cold Chain Equipment Optimization Platform (CCEOP)).[7]

Key performance features include Grade A user-independent freeze protection, meaning that without any human action these appliances ensure vaccines are not exposed to damaging freezing temperatures. They also possess greater holdover time, i.e. the number of hours that an appliance remains below 10°C during power outages. Finally, these innovative cooling

[1] Kenya National Cold Chain Inventory, 2016 and 2021

[2] https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=KE

[3] Kenya National Cold Chain Inventory, 2016

[4] Costs are based on reported facility expenditure in 2016 and are inclusive of logistical expenditure (i.e., motorbike fuel).

[5] Ibid.

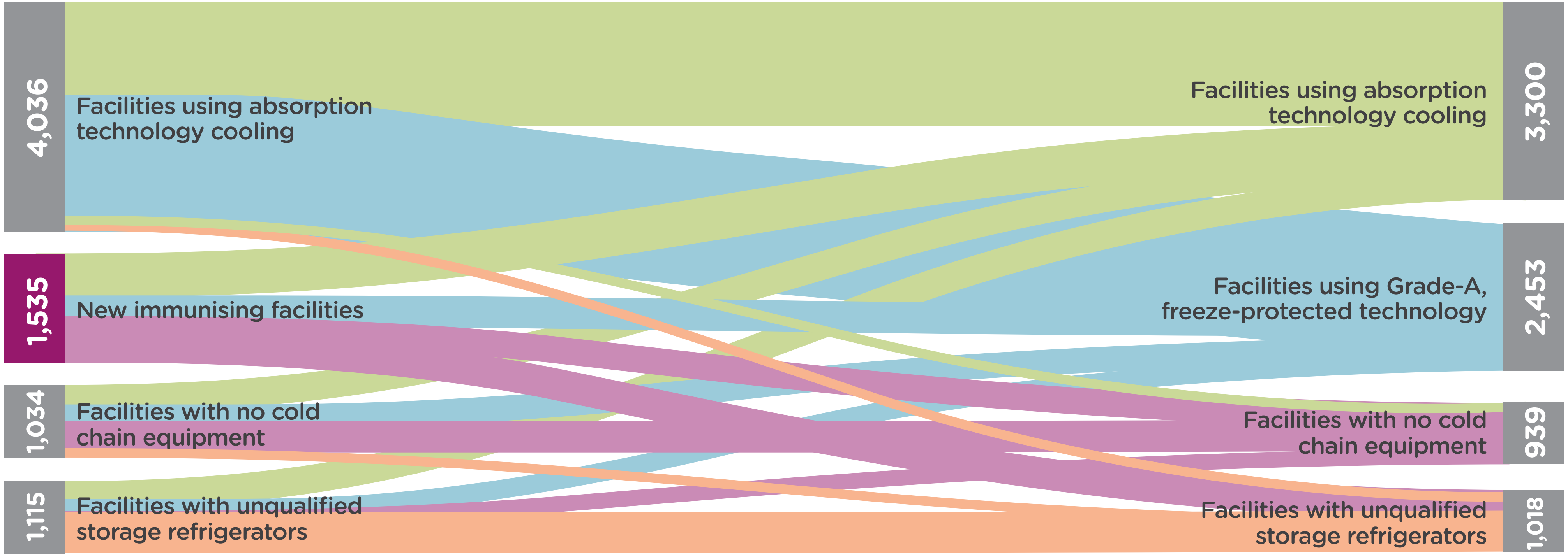
[6] Kenya Temperature Monitoring Study, 2018

[7] Cold Chain Equipment Optimisation Platform: Technology Guide, Gavi, 2019

solutions can operate at higher ambient temperatures and are equipped with voltage protection that will maintain functionality in volatile power conditions.[8] Importantly, they do not use any fossil fuels for power, resulting in a climate-friendly cold chain that is often more cost-effective over its lifespan.

The effort to update Kenya's cold chain inventory began in 2016 with the country's successful application to Gavi's CCEOP and a World Bank loan that resulted in the deployment of 3,082 new refrigerators. 20 percent of these appliances were solar-direct drive (SDD) refrigerators, which use solar energy via photovoltaic panels to maintain the required 2–8°C for vaccine storage. SDD refrigerators allow for expansion to health facilities with no electricity, are low maintenance and have low OPEX costs as they do not require a battery, electricity, or backup power source. The remaining 80 percent of appliances procured were ice-lined refrigerators. While they are mains-powered, the water or PCM-based coolant packs lining the walls enable long holdover times – a minimum of 20 hours and often more than two days.

FIGURE 4.3: PROGRESSION OF OPTIMIZATION OF THE VACCINE COLD CHAIN IN KENYA, 2016–2021



[8] Cold Chain Equipment Optimisation Platform: Technology Guide, Gavi, 2019

As shown in Figure 1, 2,463 units of optimal CCE were introduced to Kenya through these investments over a five-year period, increasing the rate of optimized equipment to 33 percent by 2021. This was accomplished through a blend of deployment across sub-optimal sites, new sites, those with unqualified storage refrigerators[9], and facilities that previously had no CCE. The number of sub-optimal sites decreased by 18 percent (4,036 sites to 3,300), however, this figure also accounts for the introduction of new sub-optimal equipment at other site types.[10]

In 2021, these Grade A refrigerators directly contributed to vaccine administration for 833,238 infants out of a total population of 1.7 million (50 percent) despite only comprising a third of the total CCE.[11]

The road to success

Despite its success in deploying 8,342 refrigerators to date, Kenya now faces the challenge of maintaining the CCE. The current staff of 490 cold chain technicians are insufficient in number and face the additional challenges of limited transportation and technical resources that hinder their ability to respond to CCE malfunctions effectively and efficiently.[12]

While considerable progress has been achieved to date through nearly 50 percent equipment optimization and 92 percent functionality rates, continued expansion of the cold chain will inevitably result in increased maintenance needs. Kenya's cold chain expansion proves that this ecosystem is only as strong as its weakest link. There is a need to strengthen the cold chain holistically, rather than in silos. Integrated planning, increased budgetary allocation aligning equipment scale-up with maintenance resources, and a systems approach must be firmly in place to ensure the sustained national scale-up of this lifesaving equipment.

[8] Cold Chain Equipment Optimisation Platform: Technology Guide, Gavi, 2019

[9] Unqualified storage refrigerators refer to equipment not designed for vaccine cold chain.

[10] Kenya National Cold Chain Inventory, 2021

[11] Ibid.

[12] Ibid.

HEALTH SERVICES

Nexleaf Analytics: Protecting medicines and vaccines through data analytics across the cold chain

Photo credit: Nexleaf Analytics

A decade ago, Nexleaf deployed the first ColdTrace sensor devices on vaccine fridges in rural clinics, bringing the same type of technology and data visibility that was already protecting high-value national vaccine stores to small health facilities in remote locations. This technology — remote temperature monitoring, or RTM — was initially viewed by many in the sector as too high-tech, too specialized and too costly for rural settings. However, thanks to data provided by Ministries of Health personnel, ColdTrace has expanded beyond the pilot phase and achieved large-scale distribution since 2018 to ensure effective cooling across the entire vaccine cold chain.

Gathering real-time and continuous temperature data

What we have learned in recent years is that when countries can see into their cold chain, decision-makers at all levels of the health system have a shared, objective understanding of cold chain performance. They can make informed decisions around planning, procurement and maintenance, and most importantly, they are better equipped to keep vaccines safe and potent. RTM devices automatically gather real-time, objective and continuous temperature data from vaccine storage and transport equipment, share those data with multiple stakeholders, and automate alerts and dashboard analytics that synthesize and contextualize the data.

The system saves health workers time by automatically and remotely collecting data, and it eliminates opportunities for human-prone errors from paper-based systems. It also provides a cost-effective and customizable way for countries to own their data, identify problems, procure and maintain equipment, and maximize their capacity for safely refrigerating their vaccine supplies.

ColdTrace currently protects vaccines for one in ten babies born around the world every year. The system has been shown to reduce damage to vaccines by heat and cold by 68 percent and 67 percent, respectively. Helping countries avoid vaccine degradation due to temperature exposure — high or low — reduces waste and ensures effective immunization, ultimately reducing outbreaks of disease.

Kenya and Tanzania are currently partnering with Nexleaf to get the right data to the right people at the right time, providing Ministry of Health personnel with the information they need to keep their fleet of vaccine fridges and transport carriers up and running. In December 2021, staff at a district vaccine store (DVS) in Tanzania received SMS alerts concerning a couple of faulty fridges and after looking at the data analytics, it was clear there had been a power outage. These data prompted a fast response from the DVS staff and power company who were able to resolve the issue within a few days, restoring reliable cooling to a store that plays a critical role in assuring the safety of thousands of vaccines distributed to local facilities.

Tracking COVID-19 vaccines in Kenya

This real-time visibility into cold chain performance took on an even greater significance in early 2021 when countries started receiving thousands of doses of COVID-19 vaccines; Nexleaf's work in remote temperature monitoring during transportation was well underway when the Kenya Ministry of Health requested sensor devices to monitor its valuable Pfizer and Moderna COVID-19 vaccines to ensure they stayed safe. So far, Nexleaf's battery-powered and Bluetooth-enabled Trek device has been used to monitor all the transport routes of Pfizer (795,600 doses) and Moderna (880,000+ doses) vaccines that have been transported from the central vaccine store to the nine regional vaccine stores throughout Kenya.

The data collected via Trek are shared with health workers to show how the vaccines fared throughout the journey, providing evidence that vaccines are still potent and will protect the population effectively. The data are also organized into various visualizations that Ministry personnel can use to evaluate which vaccine distribution events maintained safe temperatures most effectively. These analytics have allowed for evidence-based discussions around the vaccine cold chain, not only for COVID-19 vaccines, but all childhood vaccines. With very clear protocols around vaccine temperature requirements and vaccine viability, health workers can use Trek data to make informed decisions rather than relying on guesswork, dispose of spoiled vaccines, and take steps to protect vaccines before they lose potency.

Key to the value of remote temperature monitoring is the remote and automated nature of the data the system gathers. Using sensors to log and upload temperature and power availability data, the system eliminates error-prone manual data entry and enables push-button time-series data visualization. It can also provide insight into health facility power capacity, revealing how many hours of grid power flow to the facility, or whether a solar-battery system is functioning properly. Trek provides GPS route data that can give planners visibility into the locations and timing of problems that hinder efficient vaccine delivery.

As we look to the future, we believe the key to total system improvement lies in full end-to-end RTM at every storage point and transport leg of the vaccine cold chain. By 2025, we hope to see end-to-end RTM implemented in three low- and middle-income countries (LMICs), generating critical data to safeguard vaccines.

Our most crucial measure of success, however, is seeing evidence that the central Ministry of Health, health workers and personnel at every level are using data gathered by the system to guide their actions in their day-to-day work as well as in their country-wide cold chain planning, procurement and management. We also believe that the system will achieve its maximum utility when power availability and Trek route data can be leveraged effectively to provide benefits to planners beyond vaccine management, as more lifesaving equipment (such as oxygen concentrators) and critical medicines (such as insulin) are deployed to more and more remote clinics.

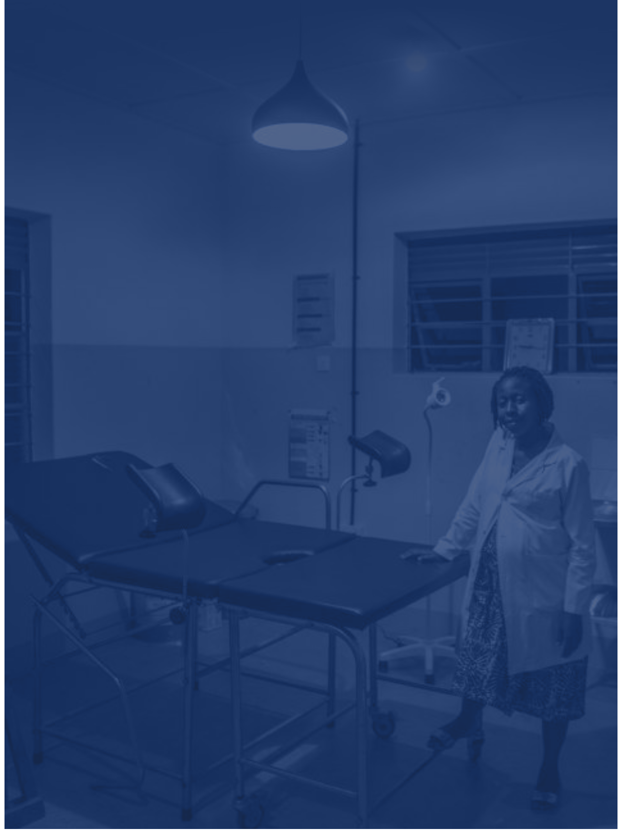
Meet our Global Panel on Access to Cooling member from Nexleaf Analytics

Nithya Ramanathan

Chief Executive Officer and Co-founder, Nexleaf Analytics

HEALTH SERVICES

SEforALL Powering Healthcare Programme: Advancing health facility electrification



The COVID-19 pandemic has emphasized the importance of reliable power for health service delivery and has led to increased momentum in global interest to address the challenges that surround health facility electrification. While decentralized renewable energy solutions present an opportunity to deploy efficient solutions in a rapid and cost-effective way, barriers such as the availability of reliable data, long-term sustainability and innovative financing mechanisms, and effective coordination remain. In response to the COVID-19 pandemic and the resulting investment need for the health sector, SEforALL continues to leverage its longstanding Powering Healthcare programme to work with governments and their development partners to build the evidence and solutions needed to achieve universal electrification of health facilities by 2030.

Measuring the impact of health facility electrification

Electricity is generally understood as a prerequisite to almost all aspects of a well-functioning health facility, but it is often difficult to measure or quantify the direct impact of electricity on health outcomes due to its many determinants and contextual factors. Therefore, impact is often measured indirectly through the lens of a specific aspect of health services, which can include service delivery, preventative care, vaccine storage and delivery, maternal health, and health-seeking behaviour. These pathways are examined in SEforALL's recently launched Powering Healthcare Impact Factsheet, which compiles existing, published studies on the linkages between reliable power at health facilities and improved health outcomes.

While there are still several gaps in better understanding and specifically in quantifying the impact of reliable energy on health outcomes, the available research supports the importance of reliable power in the health sector. For example, a study in India found that primary healthcare centres without access to electricity had 64 percent less deliveries, 39 percent less in-patients, and 38 percent less out-patients.[1] Another study in Zambia found the acquisition of solar-powered microscopes led to a 25–30 percent increase in the number of people tested for tuberculosis (TB), contributing towards the increase in the TB cure rate from 62 percent to 72 percent in the area.[2]

Women are also disproportionately affected by low levels of electricity access, with a study in Uganda revealing that electricity had the

[1] https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0252705

[2] https://www.tandfonline.com/doi/abs/10.1080/09709274.2008.11906112

second highest protective effect on maternity health after availability of midwives, reducing the case fatality rate by 61 percent.[3] While these data points provide a general understanding of the importance of reliable energy in a health facility setting, additional investment in impact data can allow the sector to better understand and quantify the impact that reliable power can have on health service delivery and health outcomes.

Taking stock of global efforts

To gain a better understanding of global progress and identify potential opportunities for coordination, SEforALL circulated a sector-wide survey to document past (2015-2020), ongoing, and future health facility electrification interventions. Analysis of the resulting dataset, which includes more than 270 interventions by 81 organizations across 56 countries, showed an increase in the number of interventions, from 118 completed to 152 in the pipeline. Furthermore, the scale of interventions was larger, from 5,590 facilities targeted in completed interventions to 15,868 facilities targeted in ongoing/planned interventions.[4]

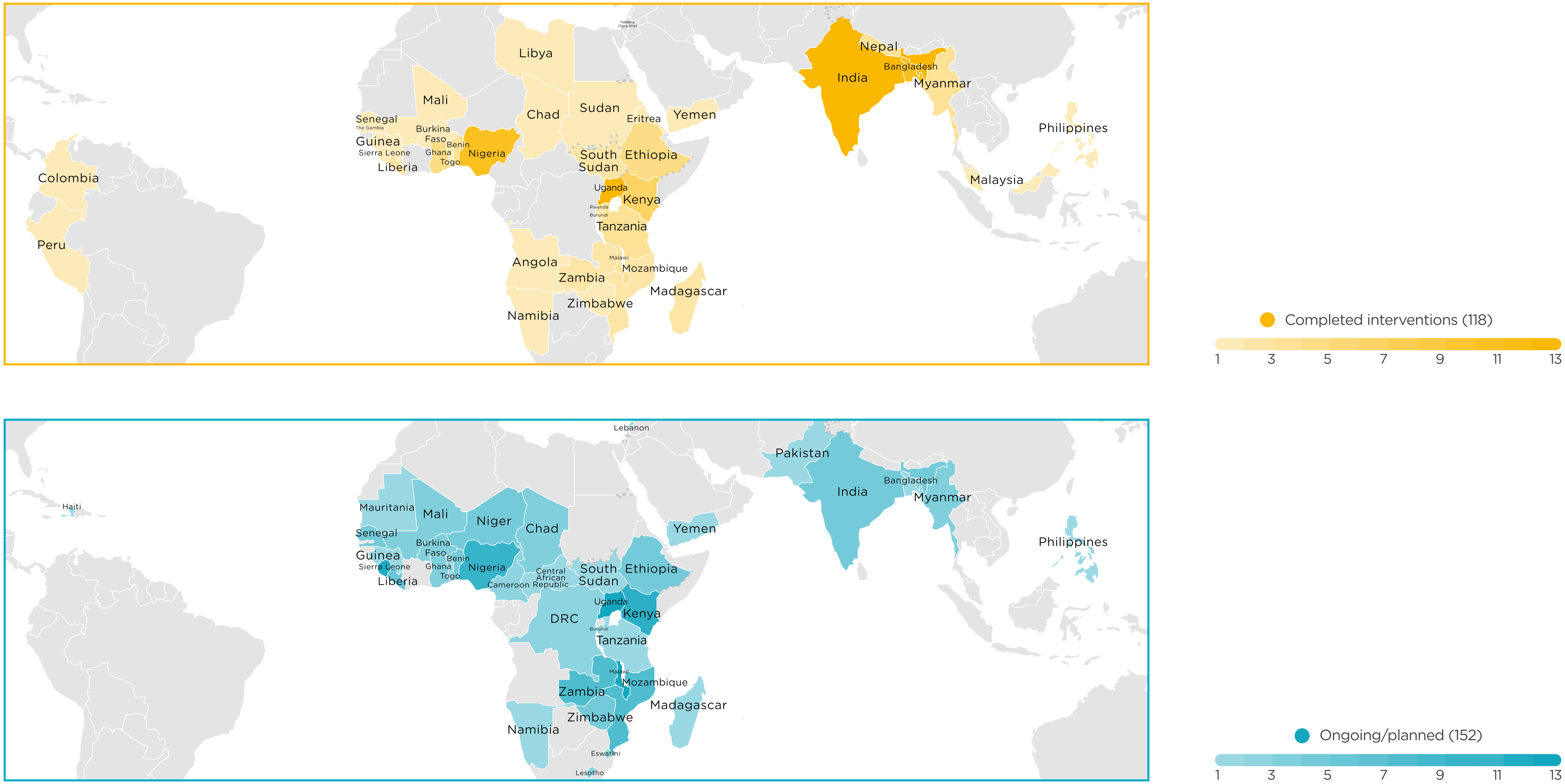
The survey also found that ongoing and planned interventions significantly favour the deployment of larger systems (above 1kWp), showing that increasingly organizations are including facility-wide energy needs in their project design. This trend could also be attributed to the significant decline in solar PV system costs in the past decade (by 82 percent between 2010 and 2019),[5] allowing implementation agencies to deploy larger solutions that can power more loads.

[3] https://obgyn.onlinelibrary.wiley.com/doi/full/10.1016/j.ijgo.2007.05.019

[4] As of 20 April 2022. For updated numbers, please visit the Powering Healthcare Intervention Heatmap

[5] https://www.irena.org/publications/2020/Jun/Renewable-Power-Costs-in-2019

FIGURE 4.4: HEATMAP OF COMPLETED AND ONGOING HEALTH FACILITY ELECTRIFICATION INTERVENTIONS



Country-level market assessments

To complement efforts to measure global progress of health facility electrification, country-level assessments present a key opportunity to analyze the energy access gap in the health sector in a more granular way, as well as identify the most appropriate technological and financial solutions to electrify health facilities at a national level. SEforALL and several other organizations are currently developing these types of country-level assessments, which can provide an important stepping stone towards project development. For example, SEforALL recently published the Powering Healthcare Market Assessment and Roadmap for Nigeria, which it developed with support from Power Africa and in close coordination with the Rural Electrification Agency and the National Primary Health Care Development Agency. This country-level assessment aims to provide the Government of Nigeria and its development partners with a data-driven overview and practical recommendations for planning and coordination of electrifying the country's underserved health facilities. The analysis estimates that there remains an energy access gap in the public health sector of approximately 30 to 40 percent, primarily in primary health care facilities. The document also highlights a USD 525 million investment need to equip 10,000 primary healthcare centres with reliable and renewable power and keep them operational for 15 years.

Building a global, multilateral, intersectoral platform

To overcome implementation barriers and achieve the goal of universal electrification of health facilities, stronger global ambition and increased coordination is needed. To address this, SEforALL and Power Africa led a coalition of organizations from both the energy and health sectors around a Multilateral Energy Compact for Health Facility Electrification, which was launched during the High-level Dialogue on Energy in September 2021. To raise global ambition, the Energy Compact has set a global, sectoral target of electrifying 25,000 health facilities with clean and reliable power solutions by 2025. The compact also targets challenges in data, coordination, and implementation models by setting ambitions to invest in better data. The Energy Compact also complements the Strategic Roadmap on Health and Energy under the Health and Energy Platform for Action (HEPA), a platform hosted by the World Health Organization (WHO) for energy and health stakeholders to coordinate their efforts to achieve Sustainable Development Goal 3 (SDG3) and SDG7 in parallel.

As the data and interventions referenced above show, the energy access gap is still significant, and progress is slow. Significant barriers remain, most notably on data availability, long-term sustainable delivery models, and innovative financing. However, the last few years have seen a significant upshift in both momentum and interest to address the issue of energy poverty in the health sector. To achieve the goal of universal electrification of health facilities by 2030, maintaining this momentum and strengthening intersectoral coordination will be crucial.

HUMAN COMFORT AND SAFETY

Adrienne Arsht-Rockefeller Foundation Resilience Center at the Atlantic Council (Arsht-Rock): Solutions for extreme heat resilience

Governments and organizations seeking to protect people from extreme heat face three major challenges. First, there is a wide and potentially lethal gap between public awareness of extreme heat risk and the real danger posed by it. Second, extreme heat is a multi-disciplinary threat that requires broad expertise in our response to it. Third, the responsibility for extreme heat response efforts is often spread across many agencies with little or no central coordination.

Since 2019, Arsht-Rock has emerged as one of the central actors tackling these challenges, alongside a diverse number of experts and partners. Arsht-Rock is working to raise awareness of the dangers of extreme heat, break down silos between government agencies and mainstream heat into local and national policy, implement heat-risk reduction and preparedness solutions, and advance tools to finance and transfer the risk of heat resilience – all with a focus on the most vulnerable populations.

Closing the heat awareness gap

To make heat warnings easier to understand and drive more public action in advance of a heat wave, Arsht-Rock has partnered with organizations and local governments to pilot the first-ever heat warning system based on human health outcomes. This system has been paired with a heat wave categorization process and a naming classification, similar to that used for hurricanes, to allow cities and their residents to clearly understand the risks of coming heat waves and what action to take. The first-ever heat wave warning system based on human health outcomes will be piloted in Athens, Greece and Seville, Spain in summer 2022.

In addition, Arsht-Rock has developed the *Heat Season* framework to help mayors and local leaders communicate the dangers of hot weather and to share practical tips for protecting people during chronic heat and extreme heat events. The **campaign** is available in six languages and has been adopted by over 12 American, European and African cities and counties.

#HeatSeason social media campaign

Finally, Arsht-Rock has begun to build a business case for action on heat. In August 2021, it released ***Extreme heat: The economic*** *and social consequences* for the United States with analysis conducted by Vivid Economics. The report examines US labour productivity losses, mortality, and agricultural commodity loss/pricing and food insecurity due to heat today and under future climate scenarios. The study estimates economic losses from heat to be at least USD 100 billion annually, a figure it expects to double by 2030 and quintuple by 2050. The Biden Administration later cited this analysis in its announcement of a landmark nationwide worker protection rule. Arsht-Rock is now developing similar studies of 12 international cities, to be released in June 2022.

Building a multi-disciplinary expert network to support implementation

In 2020, Arsht-Rock launched the Extreme Heat Resilience Alliance (EHRA). EHRA is comprised of global experts in policy, public health, humanitarian assistance, disaster management, implementation, climate risk and climate science, finance and insurance, and public infrastructure. It also created City Champions for Heat Action (CCHA) a core group of visionary mayors and leaders of organizations who are publicly committed to co-developing, piloting and implementing solutions to build heat resilience in partnership with Arsht-Rock and the EHRA that could then be scaled broadly.

Focusing the responsibility for heat response

Working with CCHA and EHRA members, Arsht-Rock helped create the role of a Chief Heat Officer (CHO) – a person tasked with protecting vulnerable people and communities from the many risks and impacts of heat. The centre has developed a suggested job description (a template for a local heat-health task force), secured essential and visible support from local political leaders, and provided seed funding to demonstrate the value of CHOs in Athens, Greece, Freetown, Sierra Leone and Miami-Dade County in the US, with the goal of having a CHO on each continent by the end of 2022. Arsht-Rock works closely with each CHO to support their local goals for heat resilience. The concept is now spreading organically, with the appointment of CHOs in Phoenix, Arizona and in process in Los Angeles, California, where legislation to create such a position is pending.

We will need to work urgently to build more heat-resilient communities. By 2025, governments, investors and philanthropists must be making robust investments in adaptation, with the knowledge that the world must prepare for the worst impacts of the climate crisis while trying to slow its advance. Leaders around the world, particularly those in areas that will be most affected by heat, must take action to protect their residents, with a plan in place for what to do when a heat wave strikes. A worldwide heat wave naming and categorization system should be established, along with appropriate early warning messaging at the local level. Further, evidence-based and innovative policies, along with financing and insurance solutions, should be explored and deployed, so that communities not only know when a heat wave is coming but also take appropriate action to protect themselves both physically and financially. People do not have to die from exposure to heat. We can make communities safer and more resilient to heat by making them more informed. This process has already started.

Meet our Global Panel on Access to Cooling member from Arscht-Rock

Kurt Shickman

Director, Extreme Heat Initiatives, Adrienne Arsht Rockefeller Foundation Resilience Center

HUMAN COMFORT AND SAFETY

Global Cool Cities Alliance: The Million Cool Roofs Challenge

Over 1 billion people across the world lack access to cooling and the implementation of passive cooling strategies is a solution to reach those most in need of cooling services. The Global Cool Cities Alliance (GCCA) works to accelerate a worldwide transition to cooler, healthier cities by advancing heat mitigation policies and programmes that reduce the effects of climate change on global warming.

Cool, reflective roofs are widely applicable – they absorb less of the sun's radiation, which can reduce indoor air temperatures by 2–3°C and outdoor air temperatures by up to 10°C. In addition to increasing thermal comfort for people who do not have the means to access mechanical cooling options, cool roofs can help reduce the need for mechanical cooling, in turn reducing energy demand and cutting greenhouse gas (GHG) emissions. There is however a lack of awareness about cool roofs and markets in which to obtain them. GCCA's successful Million Cool Roofs Challenge sought to find unique ways, informed by local conditions and ideas, to grow awareness and market availability at the local level.

A successful global initiative

The Million Cool Roofs Challenge was a highly successful first-of-its-kind global initiative to rapidly accelerate the deployment of key passive cooling solutions in highly heat-vulnerable developing countries. Ten teams were selected to receive a USD 125,000 grant to establish markets, demonstrate and evaluate local performance, raise awareness with policymakers and local leaders, and install cool roofs. In most cases, the teams were introducing the concept of cool roofs for the first time to local markets. The Challenge led to the installation of 1.1 million square meters of cool roofs by 10 teams, despite many obstacles resulting from the COVID-19 pandemic. That's an area equivalent to 250,000 small household rooftops, which effectively cooled the living, working and learning conditions of thousands of people.

But the Million Cool Roofs' successes go deeper than just the amount of area covered. Most teams reported **indoor air temperature reductions of at least 2°C, with some teams seeing temperatures drop between 4.4°C and 10°C**. The deployment of reflective materials helped the teams create hundreds of sustainable jobs and training opportunities for low-skilled workers in both rural and urban settings. One of the teams created a sustainable funding mechanism for the cool roof projects and almost all the teams have continued to work on additional roofs in both residential and public sectors.

The participants realized energy and cost savings from the reduced cooling demand and thermal comfort was improved for building occupants including school children, hospital patients and factory workers. Similarly, several of the teams were so successful that the programme helped to drive change in revising building code requirements. Kenya now requires passive cooling in its national building code and Indonesia is incorporating cool roofs into national low-income building specifications.

Impacting the local supply chain for cool roof materials

Additional benefits of the Challenge include the relationships that were established between the participants and local businesses. In several cases, new businesses were formed to address the need for cool roof materials thereby creating a local supply chain. One team noted that the supply still outweighed the demand. Research was also conducted to assess the health benefits of improved thermal comfort.

The team from Indonesia won the Challenge due to the effectiveness of their project, their collaborative approach, and their plans for scaling up their work. During the Challenge, the team installed cool roofs on 70 buildings across 15 cities in Indonesia, including 36 low-cost housing units, 10 schools, two factories and one orphanage. In total, the team estimates that 10,250 people in Indonesia will benefit from the newly installed cool roofs.

GCCA's vision is for cool surfaces (e.g., roofs, walls and pavements) to be widely adopted as a key strategy for keeping people safer and cooler in a warming world. Cooling is an essential component of modern life, fundamental for ensuring the quality of life and productivity of citizens. Yet around the world, millions of people die every year from causes related to a lack of access to cooling.

Scaling the use of cool roofs as a cost-effective, accessible, passive cooling strategy will require the development of a vibrant marketplace that ensures that materials are readily available at the community level. Success, in this case, will likely depend on the ability to catalyze the local supply chain to manufacture cool roof materials.

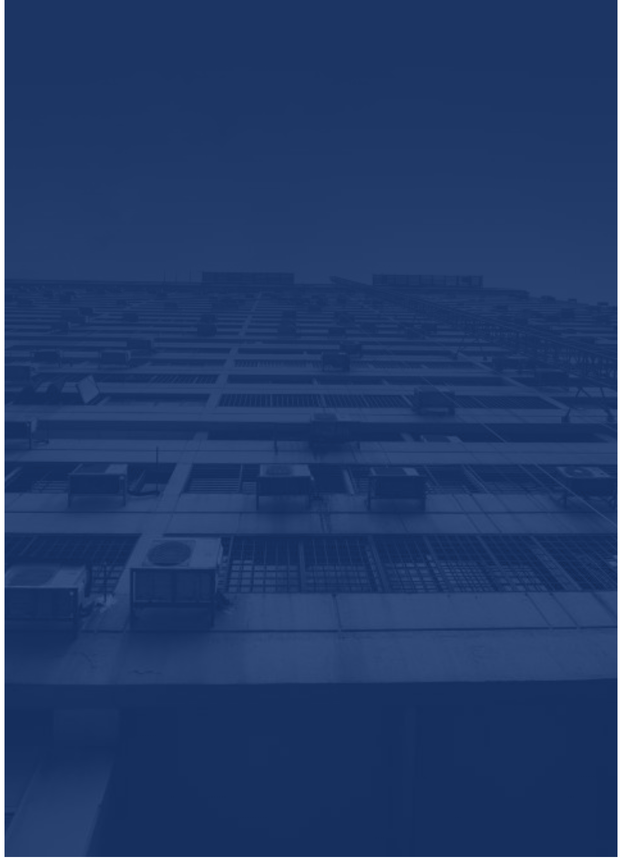
Cool roof on a school in South Africa (Photo credit: PEER Africa)

Creating a community of practice for passive cooling

Another key to success for accelerating the use of cool roofs for passive cooling is the formation of a community of practice. As seen in the Million Cool Roofs Challenge, funding is often a barrier to the adoption of new programmes that drive innovation. The community of practice would include a dedicated group that is willing to share the unique challenges of passive cooling markets and incubating solutions. The collaboration of multiple stakeholders will allow cool roofs to become commonplace, particularly in developing countries that are most in need of cooling strategies.

HUMAN COMFORT AND SAFETY

The Rocky Mountain Institute (RMI): The cooling dilemma



In many parts of the world, access to affordable cooling is increasingly viewed as a societal need. Cooling supports positive health outcomes, higher productivity, and accelerated economic development. However, over 3 billion people in the world today face some risk to their health and safety due to a lack of access to cooling.

Increasing population and rapid urbanization, coupled with a warming planet are expected to drive the number of residential/room air conditioners (RACs) in use from 1.2 billion units today to 4.5 billion units by 2050. The electricity consumption associated with today's RACs, combined with the atmospheric impact of the refrigerants used in these units, represents one of the single largest end-use risks to our global climate goals.

Herein lies the cooling dilemma: although increased access to cooling positively impacts the health, wellbeing, and productivity of people around the world, it comes at an environmental cost that we simply cannot afford.

The Global Cooling Prize: An innovation challenge that shattered the performance ceiling for residential cooling

To spur the development of a super-efficient, climate-friendly, and affordable cooling solution, an international coalition launched the Global Cooling Prize in November 2018. The coalition was initiated by RMI; the Department of Science & Technology (DST) at India's Ministry of Science and Technology; and Mission Innovation. The Global Cooling Prize was an innovation challenge focused on the RAC sector with a performance target of 5 times lower climate impact than typical units then being sold in the market. This level of performance implies 4 times lower energy consumption combined with a refrigerant that has low to no global warming potential (GWP). Together these innovations would be sufficient to solve the cooling dilemma as the access gap closes.

In April 2021, two teams — **Daikin with partner Nikken Sekkei and Gree with partner Tsinghua University** — were announced as the grand winners of the Prize. The winners were determined following the successful completion of prototype testing in India, both in an actual apartment building and under simulated real-world conditions in the lab. Both teams exceeded the 5 times lower climate impact criteria — a reduction of more than 80 percent with reference to the baseline unit (representative of the market-leading RAC in India in 2017).

Considering the operational savings due to the energy performance of the winning technologies, the total cost of ownership (i.e., cost to own and operate a unit over a 10-year period) was assessed to be about half that of traditional RACs. The winning technologies shattered the performance ceiling of what was previously believed to be technically possible for RACs, all while utilizing extremely low-GWP refrigerants and delivering on the promise of saving consumers money.

How did the prize succeed in catalyzing innovation?

Around the world, policymakers have traditionally driven energy efficiency improvements in RACs by pushing up the floor of performance through minimum energy performance standards (MEPS). While there has been a 1.7 percent average increase in efficiency per year globally since 1990, the progress lags far behind what is technically possible and what is needed to offset the massive rise in cooling demand. But it is not just about policies — most consumers focus on purchase price when making AC purchasing decisions, with little consideration given to efficiency and operating costs.

This market demand for ACs with a low purchase price has driven the industry to focus on economies of scale and cost optimization, as opposed to technological innovation and efficiency. Industry has simply followed the market. It is this market failure that is the root cause behind the sluggish pace of innovation in this sector.

The prize criteria addressed questions that the market and policymakers were not asking. This ultimately led to the successful identification and demonstration of 5 times lower climate impact technologies that have the potential to solve the cooling dilemma.

Reducing the GHG impact of cooling

Dramatically improving the efficiency and climate impact of RACs is likely the highest-impact near-term intervention that can be made in the cooling sector, considering the projected growth of residential cooling systems. **A phased introduction of 5 times lower climate impact RACs starting in 2025 would reduce estimated GHG emissions by a cumulative 68 billion tons by 2050.** But in our warming world, this alone will not be enough. We also need better buildings that keep cooler through design and passive cooling strategies, so that we don't need as much installed cooling capacity. Additionally, we need better sensing and control systems so that cooling use is dynamically matched to demand. Further innovations in all these areas will be required to reduce the building sector's massive energy and GHG footprint.

What's next?

The Global Cooling Prize successfully identified, tested, and demonstrated the next generation of breakthrough residential cooling technologies, which now need to be commercialized and brought to market around the world.

In the lead-up to COP26, the UNFCCC launched a goal as part of the **Race to Zero** initiative to achieve net-zero residential cooling by 2050. The breakthrough outcome for this goal was defined as "20 percent of global AC manufacturers bring to market affordable RACs that have 5X lower climate impact than today's units by 2025." Gree (a winner of the prize) and Haier (a partner of prize finalist Transaera), which together produce well over 20 percent of the world's RACs, both signed on to this commitment.

RMI, in collaboration with Lawrence Berkeley National Laboratory, CEPT University of India, and the Clean Cooling Collaborative, is leveraging the learnings from the Global Cooling Prize to develop test methodologies and performance standards that can accurately measure the performance of these new technologies and more closely emulate the real-world operating conditions in the global south. The recommendations from this phase of work will be made available in early 2023 with a goal of adoption by 2025, when these technologies will enter the market.

These steps will in turn support greater ambition from policymakers and regulators to undertake targeted actions to raise minimum energy performance standards (MEPS) and stretch the performance rating systems to the level of these new RACs to better inform consumers. With the right policies, consumers will understand the benefits of the new RACs as they enter the market, allowing them to save money over the unit's life cycle, provide more comfortable indoor conditions, and reduce the impact of AC use on the climate.

Global Cooling Prize Coalition

Initiated by

RMI · Ministry of Science and Technology · Mission Innovation

Lead Supporting Partners

BEE · Ministry of Environment, Forest and Climate Change, Government of India · Ministry of Power · NITI Aayog

Administered by

RMI · Alliance for an Energy Efficient Economy · Conservation X Labs · CEPT University

Sponsored by

Ministry of Science and Technology · Tomkat Foundation · Argosy Foundation · The Lemelson Foundation · Quadrature Climate Foundation · Jacobs Family Foundation · Sidney E Frank Foundation

Workforce Equity & Fiduciary Capital Advisors

VoLo Foundation · Shakti Sustainable Energy Foundation · Grantham Foundation for the Protection of the Environment

Outreach partners

Association for Energy Affordability · AIRAH · Alliance to Save Energy · ASHRAE · clasp · Coolest SG · dena German Energy Agency · eceee european council for an energy efficient economy · IGBC · IGSD · ISHRAE · NRDC · Project Drawdown · Social Alpha · Sustainable Energy for All · teri · The Climate Group · U4E · UN environment · unite · wbcsd · World Economic Forum · WWF

Meet our Global Panel on Access to Cooling member from RMI

Iain Campbell
Senior Fellow, Rocky Mountain Institute (RMI)

FINANCING ACCESS TO SUSTAINABLE COOLING

Ashden: Fair Cooling Fund

Ashden's Fair Cooling Fund, made possible by the Clean Cooling Collaborative, has shown how targeted grant funding can drive holistic support for sustainable cooling innovators. In particular, grants can be designed to encourage organizations to reach new communities and end users, laying the foundations for wider cooling access.

Through the fund, Ashden has injected a total of USD 600,000 into seven frontline cooling organizations around the world. Three of these innovators offer access to sustainable cold chain, and four support cooler homes and streets. In 2019 Ashden worked with these partners to co-create sustainable, affordable solutions targeting people in greatest danger from rising temperatures. These initiatives were launched in 2020.

In the co-design phase and beyond, Ashden facilitated peer learning, gave one-on-one support and connected organizations with experts and funders. This has helped organizations and private enterprises sharpen their focus on social impact and improve the lives of end users, particularly the most marginalized.

In some cases, grants have unlocked a business model that would have been impossible for organizations to develop without grant support. This is essential in bringing cooling to financially precarious communities.

Grants have also paved the way for deep engagement with these communities, a process that takes time and careful consideration. In addition, grants allow for more appropriate, inclusive responses to extreme heat.

The Fair Cooling Fund also featured a communications campaign telling the stories of the seven organizations. This led to international media coverage, events at COP26, Climateweek NYC and elsewhere, and a film on the cool homes challenge that was seen more than 100,000 times. Combining such a campaign with a grant-making process brings benefits for participating organizations and wider efforts to raise the profile of cooling among target audiences.

Finally, the initiative has shown the power of grants to unlock further funds. Additional investment of at least USD 1.37 million has been secured thanks to the original Fair Cooling Fund grants.

By 2025, these schemes and many others like them could bring cooling to many millions of people at greatest risk from extreme heat. But it's vital we see bolder investment from institutional funders and philanthropists, specifically to help public and private innovators reach new markets and communities. This will pave the way for support for specific solutions from mainstream financiers. It's also crucial we build bridges between the cooling and development sectors – and that we make inclusivity and community ownership key features of all cooling solutions.

The Fair Cooling Fund cohort members

India's **Promethean Power Systems** has developed and launched a milk chilling and collection service used by smallholder farmers in remote villages. Village-level collection centres allow farmers to sell into wider supply chains for the first time, reaching new markets and getting a better price. Running the centres has brought new roles and incomes for local women. In 2021 the centres supported 1,200 farmers, raising their incomes by up to 30 percent.

Cohort member **Ecozen Solutions** also supports farmers. The grant allowed the organization to more deeply understand the needs and aspirations of less wealthy farmers, and to overcome the complex business and engineering challenges that farmers have faced in getting their products to market during the COVID-19 pandemic. Through the fund, it developed and launched the EcoFrost Mini, a portable cold storeroom. The unit's small size, mobility and the fact that it can be leased make it a good option for smallholder farmers and those in remote areas. The first portable storerooms are now operational, increasing incomes by as much as 30 percent.

The Fair Cooling Fund also helped **PEG Africa** bring 45 fridges and freezers to small businesses in rural Ghana.

The fund's second focus was cool homes and communities. Consultancy **cBalance** has engaged deeply with low-income women in the Indian cities of Pune and Bangalore, to co-design affordable and sustainable solutions for cool homes. These draw on innovative roofing materials, ventilation and shading. Local engineering and architecture students have been heavily involved in this process – part of cBalance's bid to ensure the voices of disadvantaged communities are heard by city makers, now and in the future.

Those benefitting include Mangal Sanjay Shinde, a tailor who lives in a 4.5 by 3.7 meter one-room home in Pune. She said: "We used to sit outside the house from 12 pm to about 4 pm due to the unbearable indoor heat. However, we can sit indoors now."

Between 2016 and 2019 **Medellín's Green Corridors Project** brought vegetation and green spaces to the Colombian city's streets, lowering temperatures by an average of 4.5 Celsius, reducing pollution, and boosting jobs and sustainable travel. The fund has allowed the team behind this work — now part of Urban Think Tank Next — to create a business case and resources for taking this approach elsewhere. As a result, a pilot scheme has begun in the city of Barranquilla, with further interest in other countries around Latin America and the Caribbean.

In Egypt, the fund allowed the consultancy **Econsult** to engage with national policymakers and develop new green guidelines that will be central to a massive government programme of rural development, reaching 4,500 villages and small towns. The knowledge Econsult is sharing with stakeholders includes how to design cooler homes and public spaces for all. A grant of just USD 40,000 is set to create national impact.

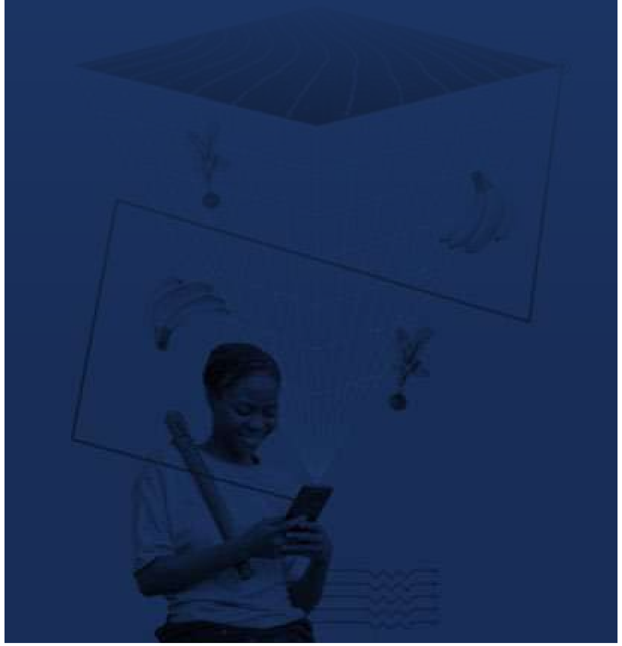
Finally, Rwandan architecture consultancy **MASS Design** used its grant to fine-tune building solutions for cool homes that are locally appropriate and develop plans to educate those who build houses about their impact.

The Fair Cooling Fund has given a diverse range of organizations space to iterate and experiment but has always helped those at greatest risk from extreme heat. These communities are being left behind by today's economies and policy decisions; the fund has shown that sensitive grant making can break through barriers and achieve radical progress.

FINANCING ACCESS TO SUSTAINABLE COOLING

Basel Agency for Sustainable Energy (BASE):

Using data science and innovative business models to strengthen agricultural cold chains in India and Nigeria



With a warming planet, growing population and developing economies, the global demand for cooling is set to triple by 2050. To address the rising demand for energy and curb the release of toxic gases into the atmosphere, in 2018 the Basel Agency for Sustainable Energy (BASE) launched the Cooling as a Service (CaaS) initiative, which significantly accelerated the uptake of clean, energy-efficient cooling technologies around the world in a way that targets sustainable business growth and mitigates the impact of cooling on the climate.

The initiative established an alliance, which today has more than 70 companies on board, and its business model has been implemented in a variety of sectors and buildings, spanning education to healthcare, industry to commerce. The model is based on the servitization strategy, through which customers purchase cooling, rather than having to invest in and operate the infrastructure needed for cooling. By removing the hurdles of high upfront investment and operation and by aligning incentives towards efficiency, the model powerfully tackles the need for cooling and addresses its impact on climate change.

Applied in agricultural cold chains, CaaS enables access to cooling for small- and medium-scale farms, increasing the quality and value of food, and reducing waste. Every year, farmers in India incur nearly **USD 12,520 million in post-harvest losses** due to inadequate storage facilities and a lack of energy infrastructure. 25 to 35 percent of cultivated food is wasted due to a lack of proper refrigeration and other supply chain bottlenecks, and only **6 percent of the food produced in India currently moves through the cold chain**. To make matters worse, information asymmetry and the lack of quality consciousness, crucial for setting the price of crops, lower farmers' ability to monetize on their produce and earn proportionately to their original investment. Many other countries face similar problems.

To address these problems, BASE and the Swiss Federal Laboratories for Materials Sciences and Technology (Empa) came together under the data.org global innovation challenge to launch the Your Virtual Cold Chain Assistant (Your VCCA) initiative in India, which was later expanded to Nigeria with the support of the German Federal Ministry for Economic Cooperation and Development (BMZ) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). Your VCCA enables smallholder farmers to access cold storage by paying per crate per day and to leverage market intelligence via an open-access, data-driven mobile application.

Cold storage providers in India and Nigeria are adopting the app to digitize key processes, such as introducing a digital inventory, which can help operationalize CaaS. Through these processes, the app provides users with post-harvest expertise to predict the shelf life of produce in storage rooms, equipping farmers with the information and technical support required to secure the best possible price for their produce.

Partners in India include Coolcrop, Oorja and Koel

Fresh, while in Nigeria the project's first partner is ColdHubs. In order to support the effective rollout of CaaS in the agricultural sector, BASE and Empa have also designed a multi-layer interactive web map by collating and visualizing different raster and vector data layers related to India's fresh produce supply chain to help stakeholders understand the potential for sustainable cooling solutions across the country. This is an example of how innovative business models can be combined with leveraging data-driven techniques to transform the agriculture sector and strengthen agri-food systems and supply chains.

By gaining access to cooling facilities and market intelligence, it is possible to improve food security, increase smallholders' income, and reduce food loss, while mitigating the impact of cooling on the environment. Currently, CaaS is being implemented in India and in Nigeria, benefitting over 500 farmers. It is already gaining significant traction and since it will be made available through open source, its adoption can be scaled up well beyond the pilot regions and countries. The innovative components of the mobile app can also be integrated into existing digital solutions to facilitate its adoption and secure a wider impact.

A large rollout of CaaS by 2025 would translate into its widescale adoption in the agricultural supply chain and improved access to market intelligence to those who need it most, reducing food loss and increasing smallholder income around the world while limiting the impact of agriculture and cold storage on the climate through the use of sustainable technology.

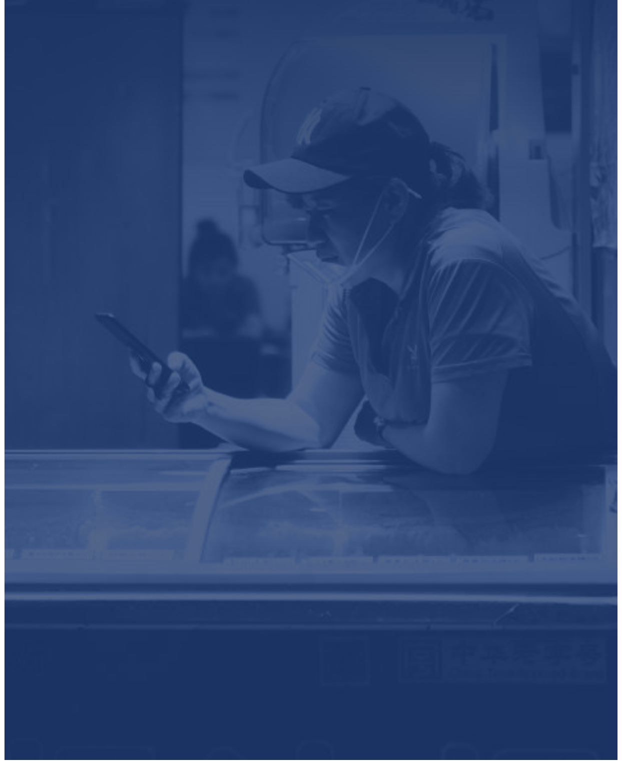
Meet our Global Panel on Access to Cooling member from BASE

Daniel Magallon

Managing Director, Basel Agency for Sustainable Energy

FINANCING ACCESS TO SUSTAINABLE COOLING

Multilateral Fund to the Montreal Protocol: Financing the replacement of harmful refrigerants



In 1991, Parties to the Montreal Protocol for the Protection of the Ozone Layer established the Multilateral Fund (MLF), the financial mechanism designed to provide financial and technical assistance to Article 5 Parties (developing countries) to the Montreal Protocol to comply with their obligations under the treaty to reduce the production and consumption of substances that are responsible for ozone depletion used in air conditioners, refrigerators and so on, and facilitate the transfer of new ozone-friendly technologies.

The MLF operates under the authority of the Montreal Protocol and oversight of its operations is through the Executive Committee whose membership comprises seven developed and seven developing countries. The Committee is assisted by the Multilateral Fund Secretariat, which is based in Montreal. The project activities are implemented by four international agencies – the UN Environment Programme (UNEP), the UN Development Programme (UNDP), the UN Industrial Development Organisation (UNIDO) and the World Bank - as well as bilateral agencies of non-Article 5 countries.

Since its inception, the MLF has supported over 8,600 projects in 148 countries including industrial conversions, technical assistance, training, and capacity building valued at over USD 3.9 billion. It has phased out 99 per cent of all ozone-depleting substances (ODS) or more than 283,000 of ozone depletion potential (ODP) tonnes of ODS consumption and 188,920 ODP tonnes of ODS production, a large portion of which are harmful refrigerants.

The success of the Montreal Protocol in phasing out ODS encouraged the global community to reduce the use of global-warming hydrofluorocarbons (HFCs), substances that are not ozone depleting but are powerful greenhouse gases that were used as replacements for ODS, especially for refrigeration and air-conditioning applications, as these were being phased out. In 2016, the Kigali Amendment to the Montreal Protocol was agreed, and included a list of 19 HFCs as controlled substances to be phased down. The MLF continues to support developing countries to reduce HFC use, following a schedule agreed under the Kigali Amendment.

A dedicated financial mechanism

As a financial mechanism, the success of the MLF can be attributed to the fact that it is dedicated only to the Montreal Protocol and as such, funding is designed around clearly defined targets and schedules, as well as specific substances that need to be phased out or phased down. Over the years, the assistance provided by the MLF to developing countries has supported a comprehensive approach: from the development of national plans that include building the capacity of recipient countries to sustain efforts to phase out ODS through technology transfer to support those industries that have to undergo conversion, to ensuring that the regulatory and policy framework to back up these actions is in place.

To slash or to trim

Emission reductions by policies/actions, bn tonnes CO_2 equivalent

Policy/Action	Cumulative emissions	Period	Annual emissions*
Montreal protocol[1]	135.0bn	1989-2013	5.6bn
Hydropower worldwide[2]	2.8bn	2010	2.8bn
Nuclear power worldwide[2]	2.2bn	2010	2.2bn
China one-child policy[3]	1.3bn	2005	1.3bn
Other renewables worldwide[2]	600m	2010	600m
US vehicle emissions & fuel economy standards†[4]	6.0bn	2012-25	460m
Brazil forest preservation[5]	3.2bn	2005-13	400m
India land-use change[6]	177m	2007	177m
Clean Development Mechanism[7]	1.5bn	2004-14	150m
US building & appliances codes[4]	3.0bn	2008-30	136m
China SOE efficiency targets[8]	1.9bn	2005-20	126m
Collapse of USSR[9]	709m	1992-98	118m
Global Environment Facility[10]	2.3bn	1991-2014	100m
EU energy efficiency[11]	230m	2008-12	58m
US vehicle emissions & fuel economy standards‡[4]	270m	2014-18	54m
EU renewables[11]	117m	2008-12	29m
US building codes (2013)[12]	230m	2014-30	10m
US appliances (2013)[12]	158m	2014-30	10m
Clean technology fund[13]	1.7bn	*project lifetime*	*na*
EU vehicle emission standards[14]	140m	2020	*na*

CATEGORIES: Energy production, Transport, Other regulations, Global treaties, Land & forests, Other

See following panel for sources and explanations

*Annual emissions are cumulative emissions divided by the relevant period. The estimate for the current emissions avoided under the Montreal protocol is eight billion tonnes of CO_2e. The annual figure for the collapse of the USSR refers to the years 1992-98. †Cars and light trucks ‡Heavy trucks

Source: The Economist: [The deepest cuts]

All developing country Parties are eligible for support from the MLF; funding is shared equitably among these countries and is based on their consumption of controlled substances. This approach assures that all developing countries are given the financial assistance they need for the phaseout and phasedown of different ODS.

Capacity building and training are an integral part of the support provided to countries to fully implement the requirements of the Montreal Protocol and its amendments. In the refrigeration and cooling sector, training for technicians supports and increases their knowledge for the safe capture of ODS, retrofitting of existing equipment and uptake of newer more energy-efficient technologies. Countries also utilize funding to increase outreach and awareness-raising activities to promote energy-efficient technologies and improvements.

Impact of the Multilateral Fund

Funding from the MLF has enabled the total phaseout of 1.75 million ODP tonnes (98.6 per cent of ODS) of chlorofluorocarbons (CFCs) that are also greenhouse gases, globally. The remaining 1.4 per cent is mainly hydrochlorofluorocarbons (HCFCs), and countries are continuing the implementation of their remaining activities to reduce the use of these substances whose phaseout date is December 2030 (except for a small service tail for refrigeration equipment).

The Kigali Amendment will phase down HFC consumption and production based on the carbon dioxide equivalent (CO2 e) by 80–85 per cent by 2045. According to the Montreal Protocol's Scientific Assessment Panel, this will avoid 2.8–4.1 billion tonnes of CO2 e (GtCO2 e) per year emissions by 2050 and 5.6–8.7 GtCO2 e per year by 2100, reducing the impact of HFCs on future global average warming in 2100 by up to 0.4°C. Replacing HFCs also creates an opportunity to increase the energy efficiency of cooling equipment by 10–50 percent, significantly reducing energy costs to consumers and businesses.

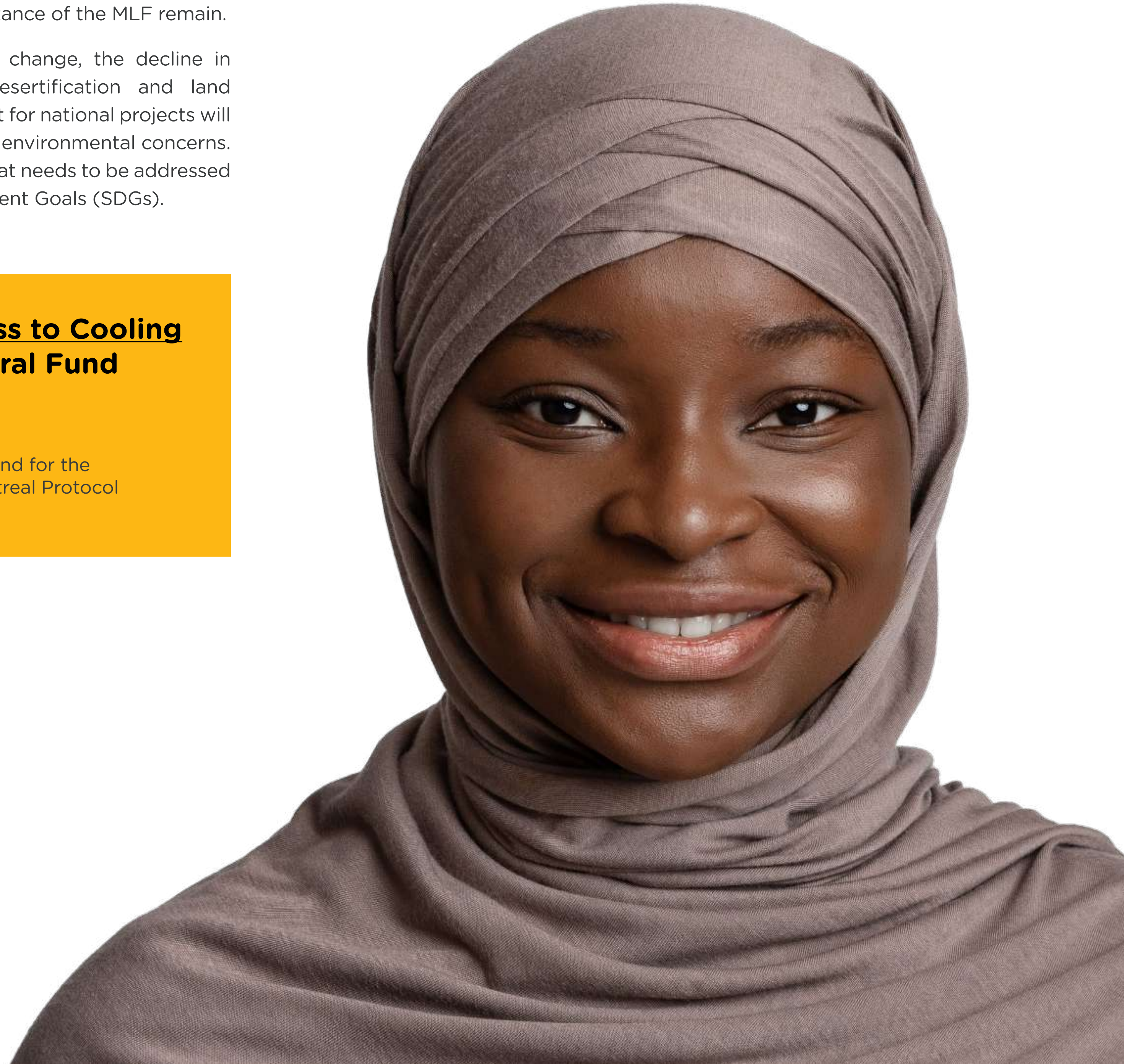
Prospects

Continuing implementation of HCFC phaseout plans and the parallel phasedown of HFCs, balancing funding and available time and resources will be a challenge for the MLF, Article 5 Parties and bilateral and implementing agencies. Recognizing the importance and intersection between ODS, energy efficiency in the refrigeration and air-conditioning sectors and other areas of work will require coordination and funding. As the world moves toward a greener future, and with the impact of ODS apparent across the environmental and climate change sectors, the relevance and importance of the MLF remain.

We can no longer look at issues such as climate change, the decline in stratospheric ozone, loss of biodiversity and desertification and land degradation as independent issues. The MLF's support for national projects will not only help the ozone layer, but also address larger environmental concerns. Cooling access has also become an important issue that needs to be addressed in the context of achieving the Sustainable Development Goals (SDGs).

Meet our Global Panel on Access to Cooling member from the Multilateral Fund

Tina Birmpili
Chief Officer, Multilateral Fund for the Implementation of the Montreal Protocol



REGIONAL PERSPECTIVES

Alliance for an Energy Efficient Economy (AEEE): Lessons learned from developing the India Cooling Action Plan

Climate change-induced warming trends, population growth and rapid urbanization are driving an unprecedented increase in the global demand for cooling across sectors, including thermal comfort in buildings, food supply chains, storage and transfer of medical products, transport of people, and industrial processes. This growth in cooling is linked with the socioeconomic progress of countries as they work to achieve the Sustainable Development Goals (SDGs). India currently has low access to cooling, but its economic progress, coupled with global warming trends, will drive an eight-times increase in the demand for cooling in the next two decades. While India's projected cooling growth is in step with its development needs, this growth, under a business-as-usual scenario, will strain existing power systems and have an adverse impact on the environment.

India's Ozone Cell of the Ministry of Environment, Forest and Climate Change (MoEF&CC), has developed a plan to harmonize the energy efficiency of refrigeration and air-conditioning equipment with refrigerant transition pathways for enhanced climate action (as agreed in the 29th Meeting of the Parties to the Montreal Protocol). Launched in March 2019, the India Cooling Action Plan (ICAP) is the first-of-its-kind initiative of its scale in the cooling sector to be taken by any country globally that underscores the urgency of proactively and collaboratively addressing cooling growth. It strikes a balanced approach to goal-setting by establishing high-level nationwide targets while allowing line ministries flexibility in setting their own targets within a directional framework of recommendations.

ICAP's high-level goals are:

- reduction of cooling demand across sectors by 20–25 percent
- reduction of refrigerant demand by 25–30 percent,
- reduction of cooling energy requirements by 25–40 percent, all by 2037–38
- training and certification of 100,000 service technicians by 2022–23
- recognizing cooling and related areas as a focus area of research under the national science and technology programme.

The Alliance for an Energy Efficient Economy (AEEE) was closely involved in the ICAP development process from inception to completion. AEEE led two of the seven working groups established for sector-specific analysis (space cooling in buildings and the food cold chain), supported the Ozone Cell in synthesizing and integrating the working-group outputs into a cohesive ICAP report, and provided strategic guidance in the Steering and the Inter-ministerial Committees.

It has been just over three years since the launch of the ICAP. Programmes and initiatives are already underway to advance the Plan, despite a slowdown due to the COVID-19 pandemic. AEEE is supporting the operationalization of ICAP through multiple avenues: as part of the Implementation Steering Committee established by the Ozone Cell, as part of the India Cooling Coalition and directly through a multi-year programme to implement ICAP recommendations.

One limitation of the ICAP development process was not including macroeconomic modelling to evaluate the impact of cooling on emissions. Incorporating such a modelling exercise would make the analytical outcomes more robust and is considered a future area of improvement. In parallel, the ongoing collaboration and alignment between the MoEF&CC and other line ministries to help effectively execute the ICAP is important.

ICAP has placed India on the international radar and garnered significant interest in supporting global momentum for the creation of National Cooling Action Plans (NCAPs). The ICAP experience has been influential in guiding the 'global' NCAP Methodology developed by AEEE under the leadership of the UN Environment Programme (UNEP) and the UN Economic and Social Commission (UNESCAP) and supported by the Cool Coalition's NCAP Working Group.

Beyond the direct application for cooling action plans in other countries, the ICAP lessons are relevant to environmental and climate-related policymaking in key areas such as sustainable urban development, greenhouse gas (GHG) net-zero pathways for cities or regions, low-climate impact mobility solutions, including the transition to electric vehicles, and waste management.

AEEE'S KEY LESSONS AND TAKEAWAYS FROM THE ICAP DEVELOPMENT PROCESS

ONE NODAL ENTITY

It requires a nodal government entity that not just 'owns' the development process but also drives effective collaboration and buy-in from multiple relevant government bodies

TRIPLE-SECTOR DEVELOPMENT FRAMEWORK

Development process should include a collaboration framework that enables the active engagement of the relevant stakeholders, drives alignment among diverse interests, and catalyses synergistic action

INTER-MINISTERIAL COORDINATION & BUY-IN

It requires a high-level steering committee or governance body that can provide oversight during the development process, help achieve cross-sectoral integration, and drive effective collaboration amongst relevant government bodies

ROLE OF DATA

First step should be to leverage and build upon existing research conducted nationally and globally, and draw information from government databases. Where reliable data is not available in the public domain – these data gaps can be plugged in by engaging subject matter experts, such as academia, civil society organisations, and industry

DOVETAILING EXISTING POLICIES & PRIORITIES

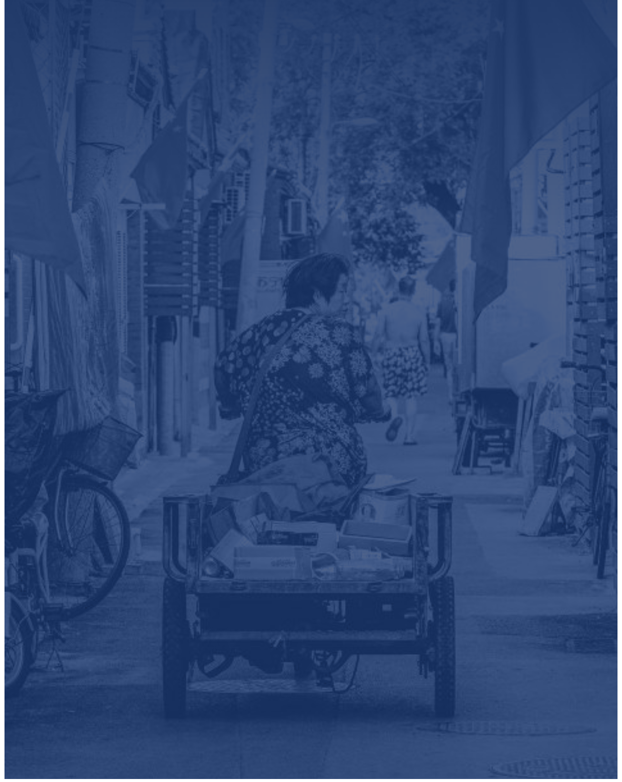
An important consideration is to align the recommended actions to the extent possible - with existing national priorities and policies and international commitments. Not only does this encourage inter-ministerial cooperation, but it also maximises potential benefits through synergistic actions

IMPLEMENTATION FRAMEWORK

It is important to instate an implementation framework that clearly outlines a monitoring protocol and establishes a recalibration process for updating the recommendation with respect to the progress made and any new information or technologies that may have become available

REGIONAL PERSPECTIVES

Building Energy Research Center of Tsinghua University: China's progress towards sustainable cooling



China's National Green Cooling Action Plan

In June 2019, China unveiled its first national Green Cooling Action Plan (GCAP), an integrated master plan with new energy efficiency and market penetration targets for air conditioners and other cooling products, driving improvements in cooling efficiency and the transition to green refrigerants. The plan was the result of an 18-month-long joint effort between key government agencies, including seven ministries, and was led by the National Development and Reform Commission (NDRC), in collaboration with research institutes, industry associations and civil society.

The GCAP sets clear targets for China's cooling sector. By 2030, the energy efficiency of major cooling products should increase by over 25 percent; the market share of green and efficient cooling products should increase by 40 percent; and the energy efficiency of large public buildings should increase by 30 percent compared to 2022 levels, achieving annual electricity savings of 400 billion kWh combined. Actions to achieve these targets include upgrading energy-efficiency standards for air-conditioning and refrigeration; increasing the supply of green cooling products; promoting cooling-efficiency retrofits; and deepening international cooperation. Following the launch of the GCAP, cooling retrofit projects were also included in the subsidy programme of China's Special Fund for Ecological Civilization Construction.

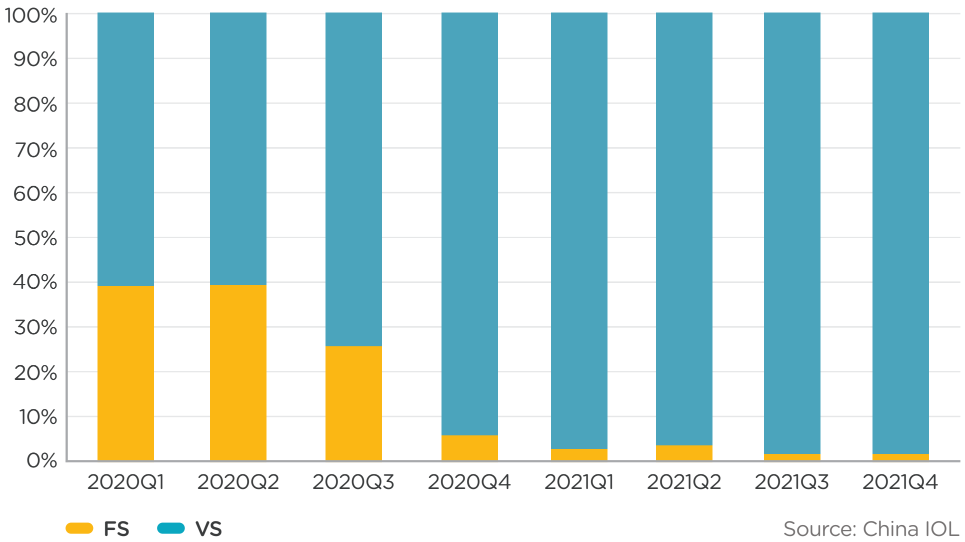
Upgraded energy performance standards to accelerate market shift

After the launch of the GCAP, and in synergy with the implementation of the Kigali Amendment, China upgraded the minimum energy performance standards (MEPS) for room air conditioners (RACs) and multi-connected air-conditioning (heat pump) units with variable refrigerant flow (VRF), the two dominant air-conditioning products for the residential and commercial sectors.

The revised standard for RACs merged requirements for fixed- and variable-frequency air conditioners, which accelerated the market transition toward variable-speed air conditioners. Today, fixed-frequency air conditioners account for only 2 percent of the domestic market (Figure 1a). Positive trends were also seen in the use of refrigerants, with the market shifting quickly away from the use of R-22 and R-410a refrigerants, and R-32 technology dominating about 80 percent of total refrigerant sales in 2021 (Figure 1b).

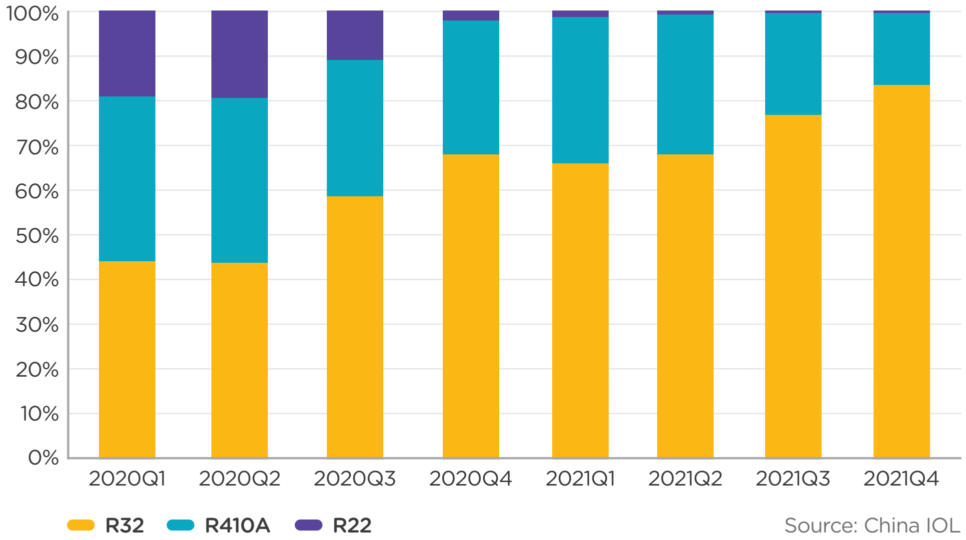
In October 2021, the revision of MEPS for multi-connected air-conditioning units led to an overall energy-efficiency improvement of 40.5 percent compared to 2008 figures. The testing method was also upgraded with a more rigorous annual performance factor (APF). Overall, the revision is expected to generate over 278 billion kWh in energy savings by 2030.

FIGURE 4.5A: DOMESTIC SALES % OF RAC BY FIXED/VARIABLE FREQUENCY ACS



Source: China IOL

FIGURE 4.5B: DOMESTIC SALES % OF RAC BY REFRIGERANT TYPE



Source: China IOL

Further opportunities for efficient technologies

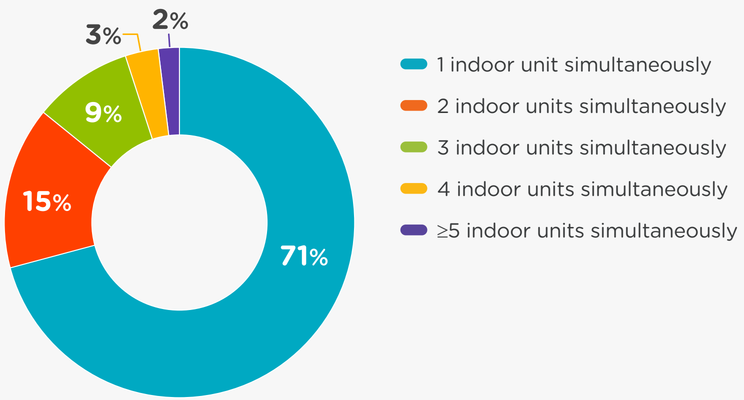
Promoting better passive building design to reduce cooling demand

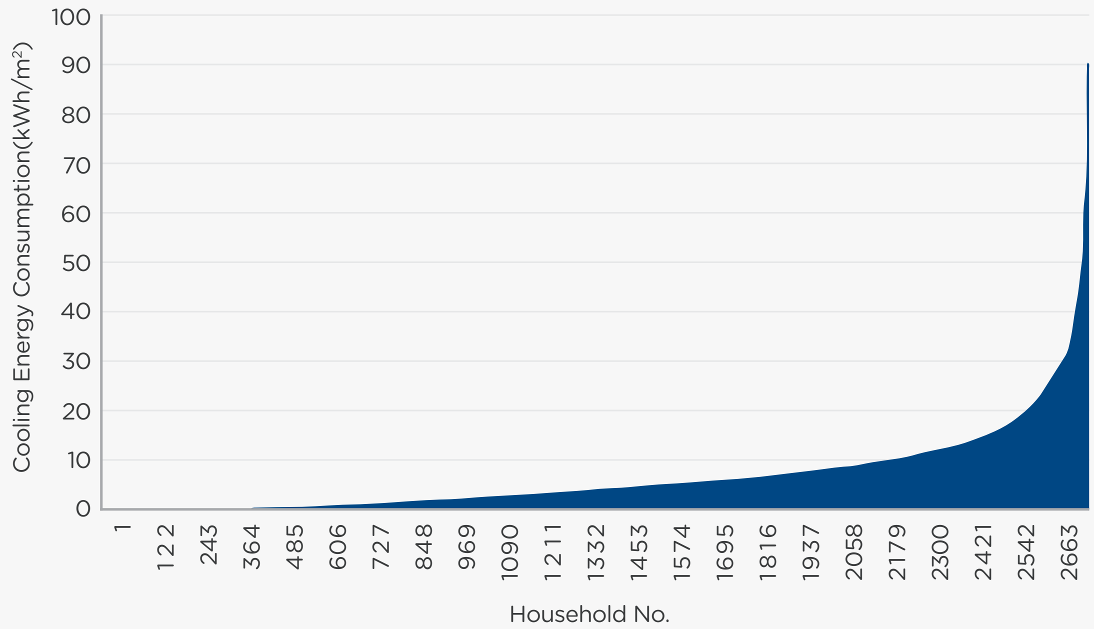
Passive building design takes optimal advantage of natural resources, including light, ventilation, shading and cooling, to create an optimum indoor environment and reduce energy demand. Well-designed natural ventilation systems save 13 to 44 kWh/m2 of cooling net energy per year. For instance, one office building in Shenzhen that has incorporated passive design has reduced the time that air-conditioning is in use by 40 percent compared with other local office buildings, while achieving the same level of indoor thermal comfort.

Meeting end users' cooling demands with decentralized cooling systems

In the past two decades, surveys on the energy consumption of buildings found that among the main drivers of variation in buildings' energy consumption are: i) the type of cooling system used; and ii) occupant behaviour patterns. Analysis showed that as much as 71 percent of the total operating time of VRF systems during one cooling season is characterized by only one unit in operation (Figure 2). In this context, centralized air-conditioning systems, provide full-time and full-space service regardless of the occupancy state of each room. Decentralized cooling systems, on the other hand, can provide a flexible, controllable part-time and part-space service, by switching off devices when the space is empty. Occupant energy usage patterns lead to further variation in energy consumption: while for most users energy consumption per unit area is below 30kWh/m2, the maximum usage can reach 89kWh/m2.

FIGURE 4.6: DISTRIBUTION OF THE NUMBER OF OPERATING INDOOR UNITS AND ENERGY CONSUMPTION



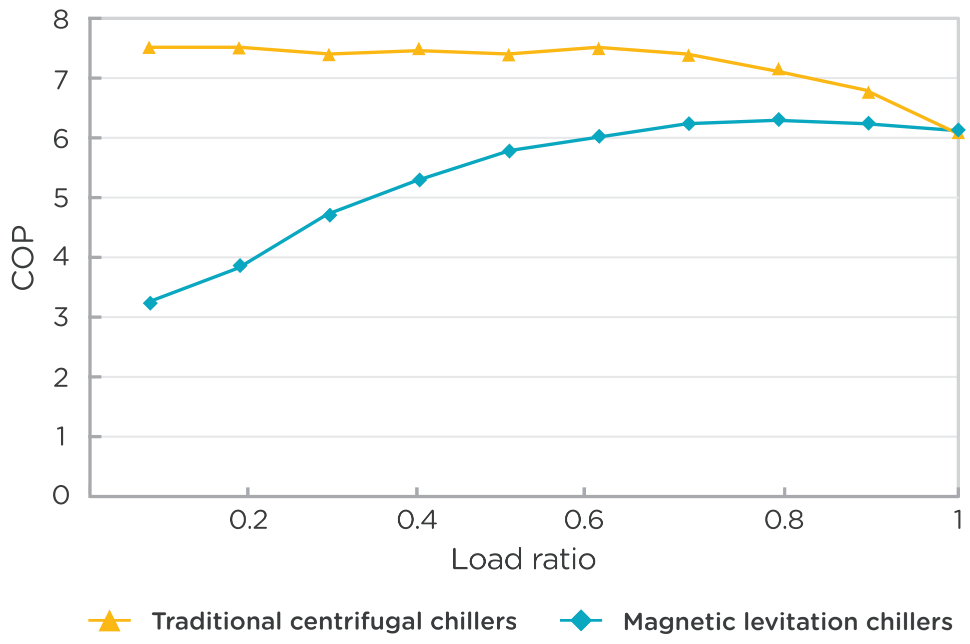


Data source: Gree analysis in 2,776 residential VRF systems (2020)

Increasing energy efficiency of cooling systems

High-efficiency cooling systems require that: i) the rated coefficient of performance (COP) of cooling devices is as high as possible; and ii) the capacity of cooling devices is adequately combined so that they operate in the high-efficiency zone at different load levels. In this context, it is important to further develop cooling equipment that can operate with high efficiency even at partial load. For instance, magnetic levitation chillers can increase cooling energy efficiency over full range, especially on a low load ratio, compared to traditional centrifugal chillers (Figure 3).

FIGURE 4.7: COP OF CHILLERS UNDER DIFFERENT LOAD RATIO



Source: Manufacturer's test results (Cooling water inlet 30°C, chilled water outlet 7°C)

A newly developed compressor technology for air conditioners shows significant potential to solve the efficiency problem at partial load. Combining a large- and a small-volume cylinder operating in parallel, this compressor greatly improves efficiency at load below 30 percent, even surpassing that of mono-split units.

New, ultra-efficient air conditioners also combine smart evaporative cooling ventilation with photovoltaic panels, which could reduce the climate impact of air-conditioning by more than 85 percent.

Replacing refrigerants with zero GWP cooling technology

Efforts to replace refrigerants in line with the Kigali Amendment currently tend to focus on deploying refrigerants with low global warming potential (GWP), zero ozone depletion potential (ODP) and high efficiency. Air conditioners are typically among the first categories of equipment that are targeted by policymakers in this area. However, solutions such as direct and indirect evaporative cooling technologies provide valid alternatives to mechanical air-conditioning, particularly for dry regions. Indirect evaporative cooling solutions consume electricity only for pumps and fan operation and do not use any refrigerant gas. Test data suggest that this solution could save up to 40 percent of energy use compared with traditional vapour compression air-conditioning systems.

Meet our Global Panel on Access to Cooling member from the Building Energy Research Center of Tsinghua University

Yi Jiang
Director, Building Energy Research Center of Tsinghua University, China

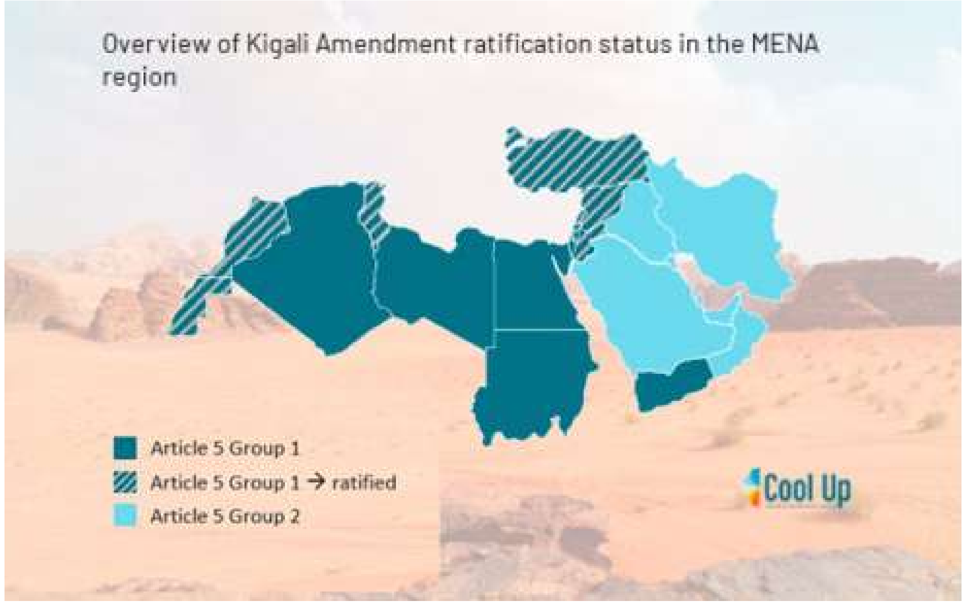
REGIONAL PERSPECTIVES

Cool Up Programme: Putting natural refrigerants on the map in the Middle East and North Africa

The story of cooling technology is a cautionary tale. The earliest cooling technologies, popularized throughout the 1800s, made use of natural refrigerants like carbon dioxide and hydrocarbons. During the 1930s, safety concerns led to the invention of new solutions: chlorofluorocarbons (CFCs). After 1980, as it emerged that CFCs were depleting the ozone layer, first hydrochlorofluorocarbons (HCFCs) then hydrofluorocarbons (HFCs) appeared to take their place. But again, a hidden environmental harm appeared. While kind to the ozone layer, both HCFCs and HFCs have high global warming potential.

Given this history, there is a high risk that the next generation of refrigerants developed to replace HCFCs and HFCs will also have unforeseen environmental consequences. Fortunately, safety standards and cooling technology have moved on since the 1800s, rendering both carbon dioxide and hydrocarbons entirely safe to use. Replacing HCFCs and HFCs with these proven natural refrigerants could avoid as much as 0.4°C (0.7°F) in global temperature rise by 2100, while helping countries meet their commitments to the Kigali Amendment as well as their Nationally Determined Contributions (NDCs).

Affordable, accessible and sustainable cooling solutions are needed across the globe. But the Middle East and North Africa (MENA) region is on the frontlines of the climate crisis and still in the early stages of the cooling transition. And the time to act is now. In Egypt, for example, average temperatures have increased by more than 0.5°C (0.9°F) in each of the last three decades, with annual electricity consumption growing by over 6 percent. By 2050, temperatures in Turkey are set to soar, with expected increases of 2.5°C (4.5°F) in east and central regions and 1.5°C (2.7°F) on the coast.



The Cool Up programme: Building a more equitable cooling future

Creating an equitable, low-energy, low-impact cooling sector is vital for the MENA region. In many MENA countries, increasing temperatures and rapid urbanization is leading to fast-growing demand for cooling and exacerbating structural challenges in the energy sector. That presents both an opportunity to create real impact and a risk of locking in unsustainable solutions. To achieve sustainable solutions for these problems at speed and at scale, stakeholders will need to work closely together.

The Cool Up programme, funded by the International Climate Initiative (IKI), part of the German government's Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection, aims to bring together regional stakeholders and revive demand for natural refrigerants by creating a sustainable cooling ecosystem. The focus is on Egypt, Jordan, Lebanon and Turkey, four countries that are well positioned to boost both energy efficiency and natural refrigerants in the cooling and refrigeration sector. While the project, which debuted in 2021, is still in its early stages, it is already bearing fruit.

To help countries meet their Kigali Amendment and Paris Agreement commitments, the Cool Up consortium focuses on enabling cooperation between government, finance and industry. Working closely with governments, the team has already identified seven different policy areas alongside multiple ministries in each country that can help accelerate the transition to sustainable cooling. Together with financial and government players, it is developing new financing solutions that will boost the cooling transition and improve access to finance for sustainable cooling technologies. Over more than 15 meetings with national financing institutes, work has begun to identify potentials and challenges for new business models for sustainable cooling financing.

At the industry level, work is underway on stakeholder engagement. The consortium has opened a dialogue with more than 30 industry players, sectoral associations and non-governmental organizations. It has begun developing demonstration projects to build trust, inspire innovation and help local manufacturers transition to sustainable cooling production lines. Buy-in has been rapid and encouraging.

Towards a just transition: Looking back to the future

The MENA region has the potential to become a leader in sustainable cooling, benefitting from job creation, reduced energy demand and increased independence from energy imports. By 2025, it is hoped that both the MENA region and the global cooling industry will appreciate that a return to natural solutions is vital for a climate-friendly future.

It is not in refrigerants alone that the MENA region will be looking to the past. Sustainable cooling solutions and modern passive cooling measures will form just two pieces of a holistic approach that also embraces reviving traditional architectural styles, utilizing locally sourced building materials, and working with ancient techniques of shading and planting. The MENA region led the world in natural cooling for thousands of years. It has the potential to do so once again in the future.

REGIONAL PERSPECTIVES

Rwanda Cooling Initiative: Unlocking financing for energy-efficient cooling in Rwanda

In 2018, the United Nations Environment Programme (UNEP) United for Efficiency (U4E) initiative, the Basel Agency for Sustainable Energy (BASE) and the Rwanda Environment Management Authority (REMA) launched the Rwanda Cooling Initiative (R-COOL) with support from the Clean Cooling Collaborative (CCC). Its aim was to aid the country's transition to efficient, climate-friendly cooling through a range of policy measures (including Africa's most ambitious minimum energy performance standards (MEPS) and labels based on U4E's Model Regulation Guidelines).

The scope was expanded in early 2021 to include the development of a financing initiative (FI), which is expected to unlock at least USD 1 million in financing for 12,500 approved appliances by 2024. The initiative was informed by the ECOFRIDGES green-on wage financing (GO) approach which had been successfully initiated by the team in Ghana as the most appropriate approach for the Rwandan market, allowing public and private sector employees to use a low-interest bank loan to purchase qualifying appliances with repayments deducted from their salaries. Like ECOFRIDGES, R-COOL FI is comprehensive in addressing recycling and capacity building.

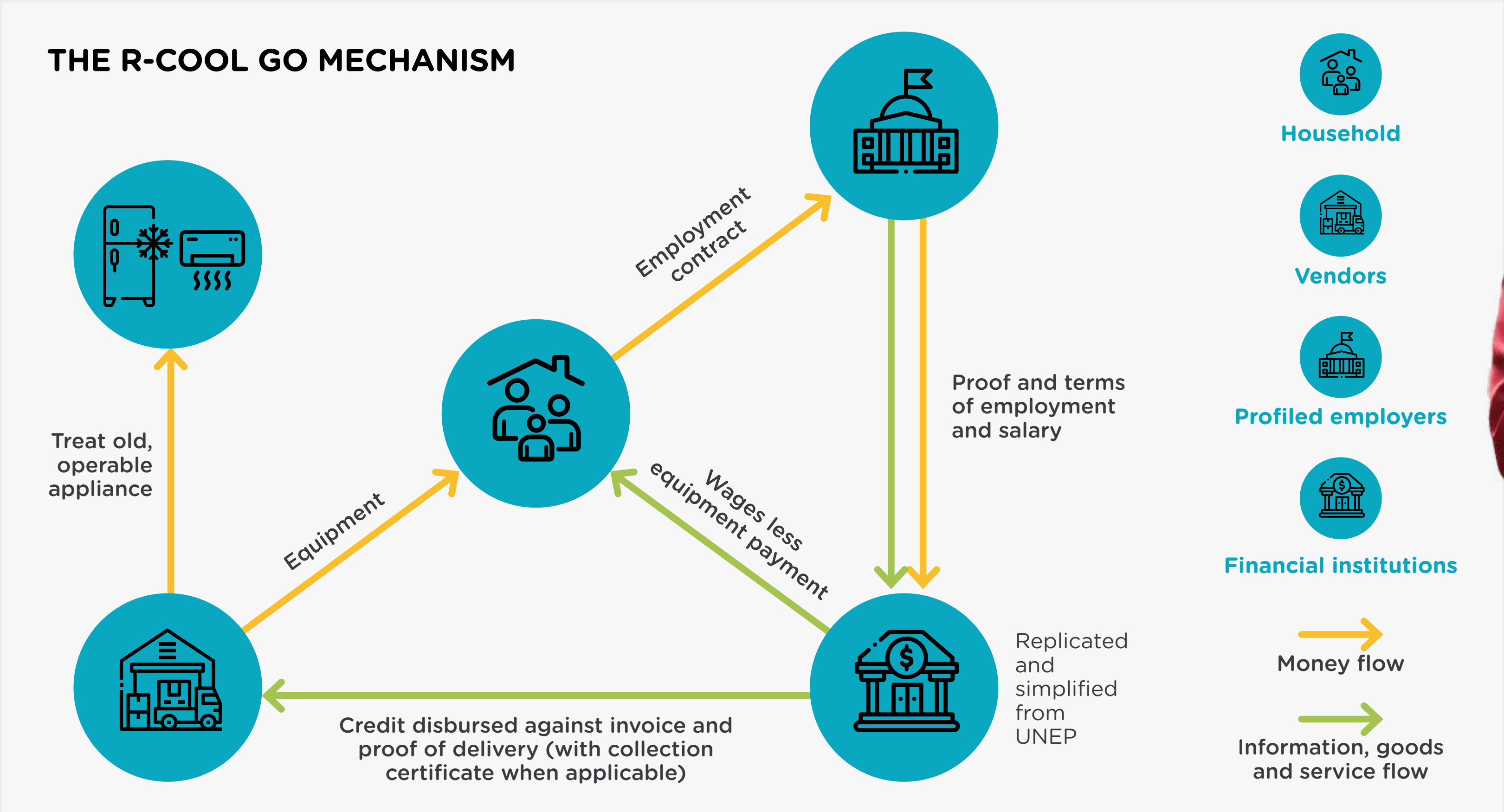
Initial technical assistance by U4E and BASE entails integrated design and implementation with local partners from the public and private sector so that a smooth handover of responsibilities is orchestrated as early as practicable for a pathway toward self-sufficiency. The emphasis is on models that are replicable in Africa and beyond where rising incomes and electricity access are driving ever greater adoption of mechanical cooling. The initiative operates within the context of the challenges of local finance, including consumer loan interest rates that are often above 20 percent.

The technical team worked with the Government of Rwanda to negotiate discounts on the manufacturer's suggested retail price (MRSP) of participating products to cover the cost of financing and offset the incentive for recycling old products. Such financial mechanisms can achieve a triple win: improve consumer access to high-quality equipment; safeguard the climate; and develop local financial intermediation services.

A robust set of well-enforced criteria, with ongoing monitoring and oversight, and compelling marketing are key to keeping all parties aligned toward the success of the programme while maintaining healthy competition among participants. These criteria should:

- Enable grid-connected households and small enterprises (on-bill) and salaried employees (on-wage) to finance efficient refrigerators and air-conditioning systems that are otherwise likely more expensive to purchase than inefficient competing products.
- For officials, link with relevant development policy targets and agreements, MEPS and labels, and opportunities to address energy security and economic competitiveness considerations.
- Provide a common set of terms and conditions that are agreed upon by all participating parties, and monitor compliance to ensure a level playing field.

- Offer capacity building for participating vendors, banks, utilities, government agencies and waste management companies to ensure they understand their roles and responsibilities – start with a pilot phase to test readiness.
- Raise customer awareness through a dedicated marketing campaign.
- Allow time for importation of products that meet the eligibility criteria, making the case through the anticipated market demand potential.
- Ensure relationship building among participating actors to ensure smooth functioning, and exchanges of information (e.g., for applications).
- Include a mix of competing vendors and banks to allow for diversity of options but with a suitable pipeline of opportunity where all can benefit.



According to Chilling Prospects: Tracking Sustainable Cooling for All 2022 over 750 million Africans face cooling access challenges, and around half are on the brink of purchasing their first air conditioner or refrigerator. Even though a high-efficiency appliance typically costs consumers much less over its lifetime (due to reduced energy consumption), than an inefficient one, the higher upfront cost is a significant barrier for them. Moreover, they have no incentive to consider which refrigerant is utilized, so inefficient products utilizing high-GWP refrigerants remain predominant.

Launch of the Rwanda Cooling Initiative's Green On-Wage (R-COOL GO) financing mechanism in January 2022

The R-COOL GO finance mechanism fixed a set of objectives and goals for newly certified sold appliances, unlocked finance, saved greenhouse gas (GHG) emissions and saved energy.

R-COOL GO FROM 2022 TO 2025 (CUMULATIVE)

Year	2022	2023	2024	2025
Refrigerators and ACs sold (no. of units)	230	752	1,644	2,995
Old appliances replaced (no. of units)	115	376	822	1,498
Finance mobilized (million RWF)	75.2	237.5	518.8	945.2
Energy savings (kWh/year)	28,000	93,000	204,000	371,000

SUSTAINABLE ENERGY FOR ALL

CHILLING PROSPECTS

Tracking Sustainable Cooling for All

VIENNA HEADQUARTERS

Andromeda Tower 15th floor
Donau City Strasse 6
1220 Vienna, Austria

WASHINGTON, DC OFFICE

1750 Pennsylvania Avenue NW Suite 300
Washington, DC 20006
USA

NEW YORK OFFICE

420 5th Avenue
New York, NY 10018
USA

Info@SEforALL.org | SEforALL.org