Closing cooling gaps in a warming world

Alessio Mastrucci, Bas van Ruijven, Shonali Pachauri (International Institute for Applied Systems Analysis, Austria)

Characterizing the cooling gap

Cooling is the fastest growing energy use in buildings and a blind spot towards sustainability (1). Cooling is fundamental for providing thermal comfort under high temperatures and the preservation of food and medicines (2). Access to cooling plays a critical role in adaptation to heat stress, and, more broadly, in addressing poverty and achieving the sustainable development goals (SDGs)(3). Heat stress is also a cause of a growing number of deaths under rising average temperatures and frequency and intensity of heatwave events induced by climate change (4). In addition, heat stress can severely affect the health, wellbeing and productivity of populations exposed to high temperatures (5).

A stark increase in uptake of air-conditioning (AC) and cooling demand is expected under increased affluence and population growth in the global south, potentially raising serious challenges for climate change mitigation (6). However, it remains unclear 1) how many people will still lack access to basic cooling under different future socio-economic and climate developments; 2) how much energy is required to provide basic cooling for all.

Recent work has assessed the extent of population lacking access to residential cooling – the cooling gap – as between 1.8 to 4.1 billion in the global South (7). The Cooling for all initiative has estimated at least 3.43 billion people still face cooling access challenges in 2021 (3), including 1.09 billion rural and urban poor at high risk, and 2.34 lower-middle income people at medium risk. This analysis shows an increase of 50 million people in the high-risk cohort compared to 2020. The cooling gap distribution is uneven across the global South (Figure 1, panel a). The regions with the highest share of population affected by the cooling gap include Sub-Saharan Africa, South Asia and South-East Asia, both because of lower income levels and hotter climate conditions in these regions.

Multiple factors contribute to determining the cooling gap. Despite the progress in access to electricity, 759 million people still live without electricity (8), especially in rural areas. Moreover, intermittent electricity supply and outages can impede even the use of fans. In urban areas, poor housing quality poses a threat with almost one billion people still living in slums (9). Slums often have poor building design and are not fit to provide adequate indoor thermal comfort conditions (10). Access to cooling devices is still limited and unequal in many contexts, as people in extreme poverty cannot even afford to buy fans, and only 8% of the population living in the hottest world regions has access to AC (1).

Cooling gap projections

Understanding the evolution of the cooling gap under different future developments is key to support policies for adaptation to heat stress and climate change mitigation. Different future socio-economic developments can significantly influence the extent of future cooling gaps. Andrijevic et al. (11) estimate the global population affected by the cooling gap between 2 billion and 5 billion in 2050 across the Shared Socio-economic Pathways (SSPs). Based on previous studies (12–14), we assess the cooling gap trends until mid-century for SSP1 “Sustainability”, SSP2 “Middle of the road” and SSP3 “Regional Rivalry” in different regions of the global South (Figure 1, panel a). Future gaps in cooling access significantly vary across SSP1-3 as a result of different demographic and socio-economic developments. In SSP1, cooling gaps progressively decrease in most regions as a result of lower population growth, higher urbanization, and higher income levels, leading to improved access to AC and progressive slum eradication (12). Conversely, in SSP3, cooling gaps worsen in many regions, due to population growth, lower urbanization, and lower income levels, entailing limited access to AC and other cooling devices and persistence of slums in cities. Sub-Saharan Africa and South Asia will be the regions with higher cooling gaps in 2050, including 74% to 79% of total population affected in the global South. In South Asia, the extent of future population affected will strongly depend on the socio-economic developments, with gaps decreasing to 0.6 billion people in SSP1 and increasing up to 2.2 billion people in SSP3. Conversely, Sub-Saharan Africa will experience increase of the cooling gaps across different SSPs, reaching 0.7 billion people (SSP1) to 1.3 billion people (SSP3) affected, due to high population growth and persisting relative low-income levels. Regions characterized by higher income levels and milder climates, including China and Latin America, will experience a decrease in the cooling gap in all scenarios.

Previous research (12, 14) has shown significant heterogeneity in access to cooling technologies across different households depending on income levels and urban versus rural locations. Lower income populations will likely face higher challenges for adaptation to heat stress being unable to afford the adoption of cooling devices and durable housing in many regions. While access to cooling will be generally higher in urban compared to rural areas, urban heat island effects might also exacerbate heat stress due higher temperatures. Different climate futures might impact both the distribution and severity of these cooling gaps.

Energy requirements

Closing the cooling gap by improving access to conventional cooling technologies, in particular AC, could entail a significant increase in energy use for cooling. Previous research has investigated the minimum energy required to provide cooling to all populations, as part of reaching decent living standards (13, 15). The total minimum energy requirements to close the cooling gap with AC and fans have been estimated at 786 TWh/yr for the entire global South, corresponding to about 14% of global residential electricity consumption (7). While different thermal comfort thresholds and behaviors can significantly influence this value, there is a great potential to reduce cooling energy requirements by technology improvements. Providing AC systems with higher energy efficiency could lead to 16% reduction in electricity requirements, while better building shell insulation could entail 34% reductions (Figure 1, panel b). While reducing energy needs, enhanced building quality could also improve indoor thermal comfort and limit the need for using active cooling systems. Taking timely action to improve the energy efficiency of buildings and cooling systems has high potential in providing thermal comfort while limiting energy requirements under rising temperatures due to climate change.

Strategies for closing the cooling gap

The results of recent research on the cooling gap show that a significant part of the population in the global South will still be exposed to heat stress risks by mid-century due to lack of adequate residential cooling comfort. Closing this gap has important implications for multiple SDGs (2) and requires holistic approaches to address its multi-faceted nature, encompassing durable housing fit for local climates, sustainable built environment and urban design, and improved access to affordable energy-efficient and low-emitting cooling systems.

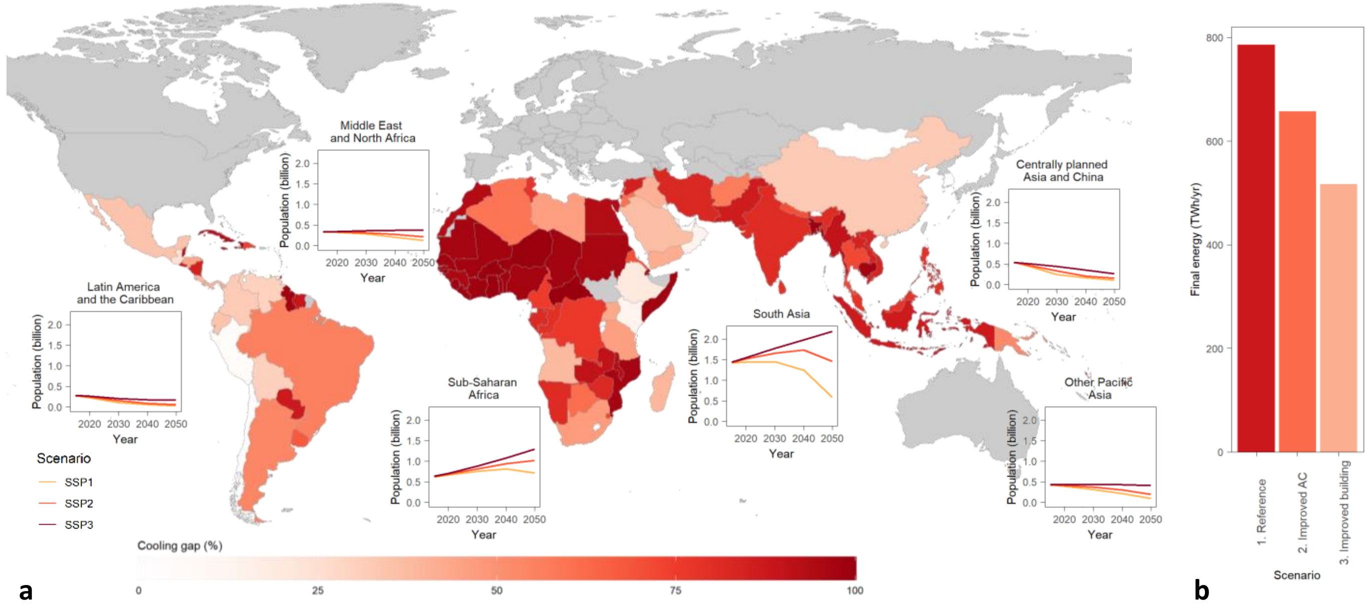
The quality of the built environment and housing construction is critically important in providing indoor thermal comfort and relief from high temperatures while reducing the need to run active cooling, and thus can help limit energy demand in the first place (SDG7). While providing adaptation to heat stress (SDG3), affordable and durable homes adapted to local climate conditions can contribute to improving living conditions and playing an important role in slum eradication (SDG11). Passive design strategies for buildings, such as shading, improved natural ventilation, and cool roofs can improve thermal comfort and reduce the energy demand for cooling. Timely implementation of building codes and policies targeting energy efficiency in new construction could play an important role in reducing the long-term buildings energy demand in the global South, as the building stock is expected to double by mid-century (16). At the urban level, green infrastructures, nature-based solutions and improved urban forms can be effective in reducing urban heat island effect and thermal comfort.

Promoting access to electricity (SDG7) and to affordable, efficient, and low-emitting cooling systems, is key for closing the cooling gap while reducing burden to the environment and reaching climate targets (SDG13). As an example, evaporative cooling can be an effective and less energy-intensive technology compared to AC in dry climates. Solar powered AC and systems with low-emitting refrigerants can contribute to lower greenhouse gases emissions, in accordance with the Kigali Amendment to the Montreal Protocol, and further contribute to reducing climate affecting emissions.

Figure 1. Panel a: Share of population currently affected by the cooling gap by country (world map) and projections of total population affected by the cooling gap for the three central Shared Socioeconomic Pathways (SSP1-3) by region1 in the global South (line charts) based on (12, 13). Panel b: Minimum final energy currently required to close the cooling gap in the global South under

[1] Regions in the global energy-economy integrated assessment model MESSAGEix. Full region definition available at the following webpage: https://iiasa.ac.at/web/home/research/researchPrograms/Energy/MESSAGE-model-regions.en.html

reference or improved technology scenarios, based on (7).



References

1. IEA, The Future of cooling. Opportunities for energy-efficient air conditioning. 90 (2018).
2. R. Khosla, *et al.*, Cooling for sustainable development. *Nat. Sustain.* **4**, 201–208 (2021).
3. Sustainable Energy for All, “Chilling Prospects 2021” (2021).
4. IPCC, “Climate Change 2022: Impacts, Adaptation and Vulnerability. Summary for Policymakers.” (2022).
5. World Health Organisation, *Heatwaves and health: guidance on warning-system development* (2015).
6. M. Santamouris, Cooling the buildings – past, present and future. *Energy Build.* **128**, 617–638 (2016).
7. A. Mastrucci, E. Byers, S. Pachauri, N. D. Rao, Improving the SDG energy poverty targets: Residential cooling needs in the Global South. *Energy Build.* **186** (2019).
8. IEA IRENA UNSD World Bank WHO, “The energy progress report SDG7: The energy progress report” (2021).
9. UN-Habitat, Slum Almanac 2015/2016: Tackling Improvement in the Lives of Slum Dwellers. 1–96 (2016).
10. A. Nutkiewicz, A. Mastrucci, N. D. Rao, R. K. Jain, Cool roofs can mitigate cooling energy demand for informal settlement dwellers. *Renew. Sustain. Energy Rev.* **159**, 112183 (2022).
11. M. Andrijevic, E. Byers, A. Mastrucci, J. Smits, S. Fuss, Future cooling gap in shared socioeconomic pathways. *Environ. Res. Lett.* **16** (2021).
12. A. Mastrucci, B. van Ruijven, E. Byers, M. Poblete-Cazenave, S. Pachauri, Global scenarios of residential heating and cooling energy demand and CO2 emissions. *Clim. Change* **168**, 1–26 (2021).
13. J. S. Kikstra, A. Mastrucci, J. Min, K. Riahi, N. D. Rao, Decent living gaps and energy needs around the world. *Environ. Res. Lett.* **16** (2021).
14. M. Poblete-Cazenave, S. Pachauri, E. Byers, A. Mastrucci, B. van Ruijven, Global scenarios of household access to modern energy services. *Nat. Energy* (2021).
15. N. D. Rao, J. Min, Decent Living Standards: Material Prerequisites for Human Wellbeing. *Soc. Indic. Res.* **138**, 225–244 (2017).
16. IEA, *2019 Global Status Report for Buildings and Construction* (2019).