THE FUTURE OF COOLING

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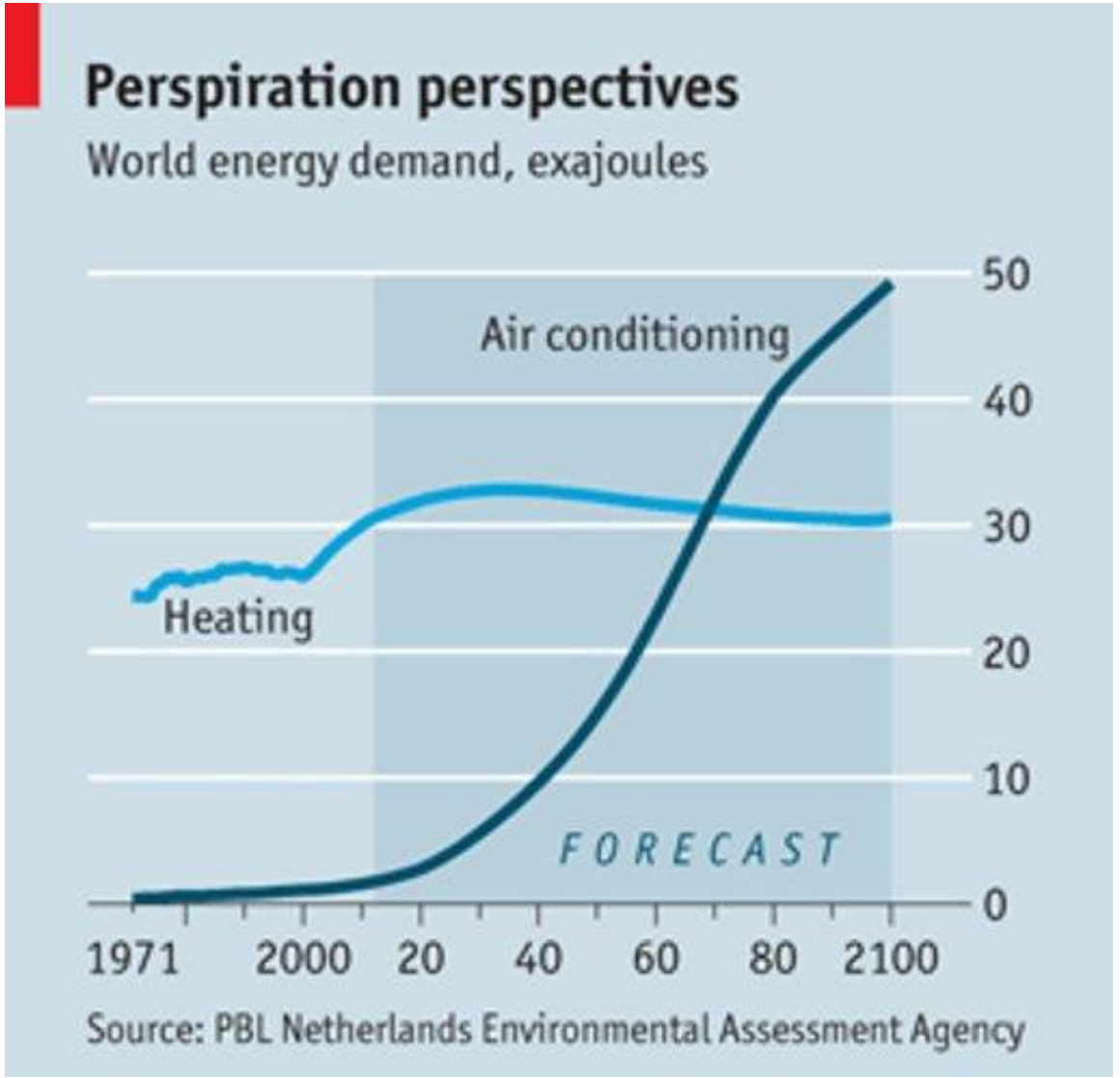
Oxford Energy Day 2022

Understanding and shaping the unprecedented future of cooling

- Equivalent of 10 ACs to be sold every second for next 30 years (IEA, 2018)
- By 2050, cooling will require additional electricity capacity larger than combined generation capacity of US, EU & India in 2016
- 1.1 billion people face immediate risks from lack of access to cooling
- Estimated cooling gap of 2-5 billion people in 2050 who are exposed to heat stress, but don't have the capacity to adapt to it with an air conditioner



Cooling for sustainable development

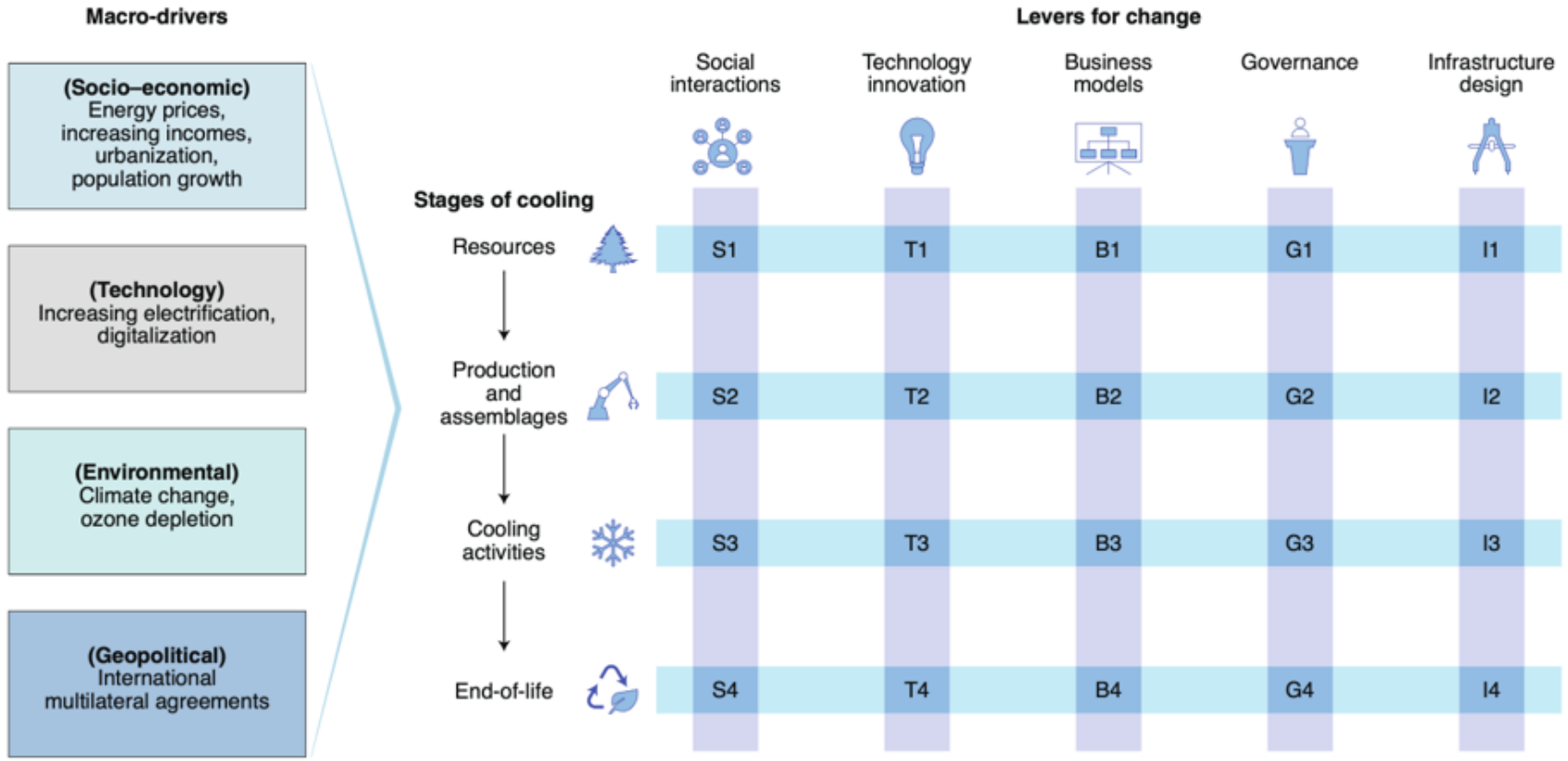
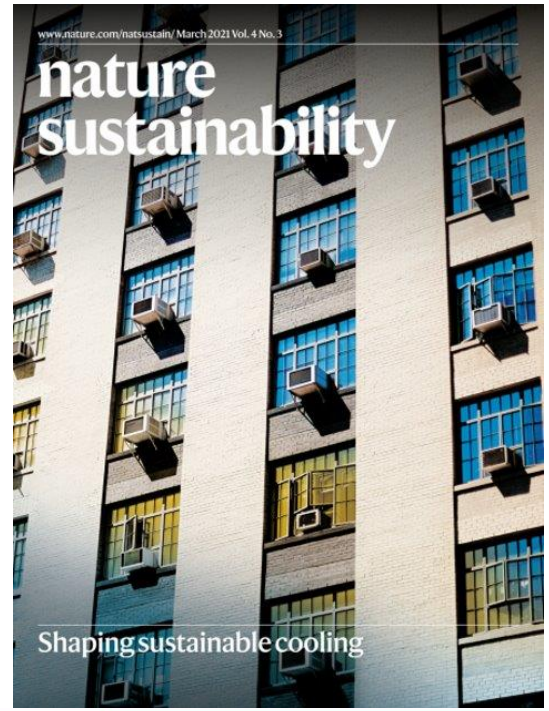


Fig. 2 | Analytical framework for transitioning towards sustainable cooling. The framework consists of macro-level drivers, the different stages of cooling delivery, and the levers which act on the cooling system to influence the trajectory of the future of cooling.



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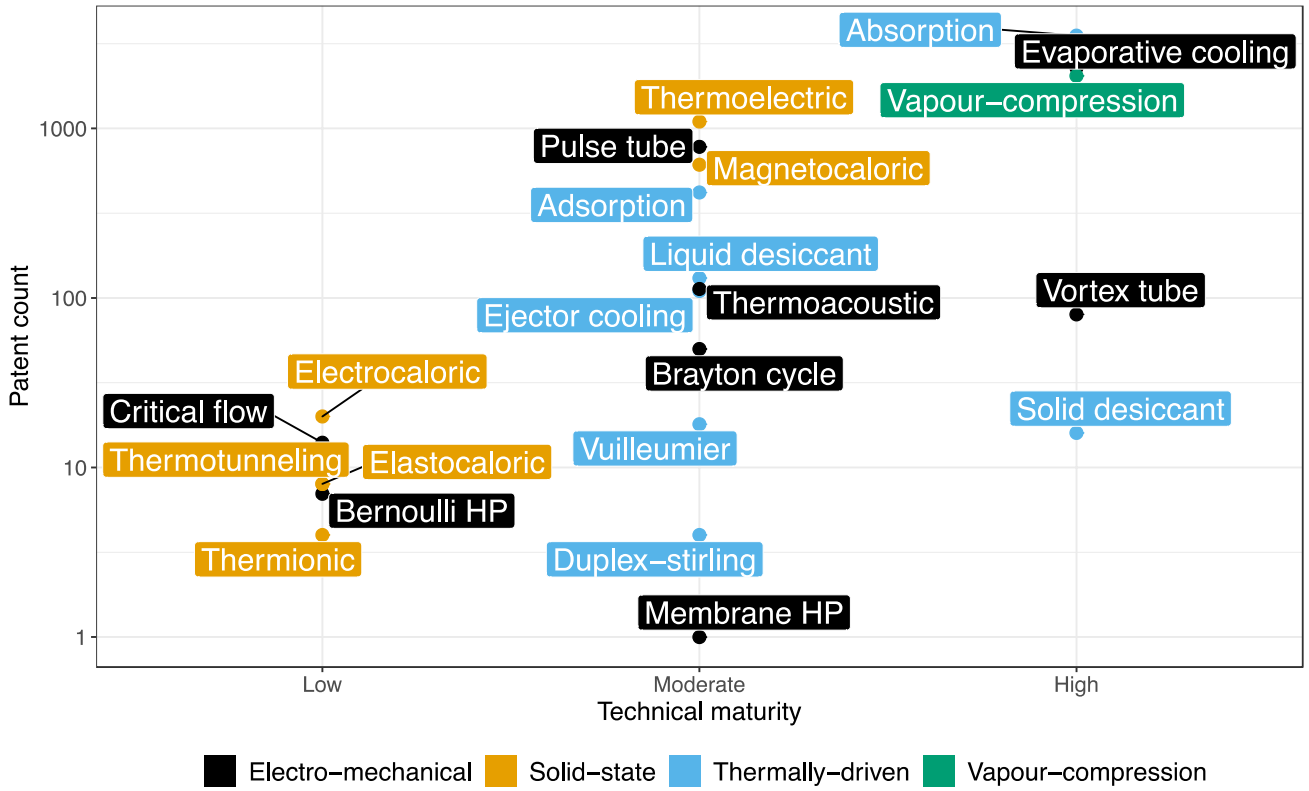
Cooling for sustainable development

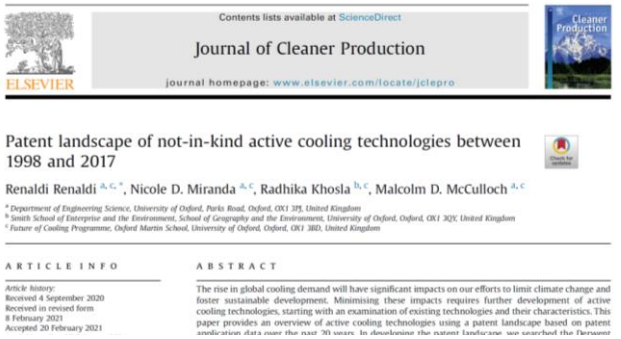
Radhika Khosla[1,2]✉, Nicole D. Miranda[1,3], Philipp A. Trotter[1,2,4], Antonella Mazzone[1,2], Renaldi Renaldi[1,3], Caitlin McElroy[1,2], Francois Cohen[1,2,5], Anant Jani[1], Rafael Perera-Salazar[1,6] and Malcolm McCulloch[1,3]

The unprecedented rise in cooling demand globally is a critical blind spot in sustainability debates. We examine cooling as a system comprised of active and passive measures, with key social and technical components, and explain its link to all 17 Sustainable Development Goals. We propose an analytical and solution-oriented framework to identify and shape interventions towards sustainable cooling. The framework comprehends demand drivers; cradle-to-cradle stages; and system change levers. By intersecting cooling stages and levers, we discuss four specific, exemplary interventions to deliver sustainable cooling. We propose an agenda for research and practice to transition towards sustainable cooling for all.

Lock-in to vapour compression air conditioning

- Top patent countries: China, Japan, South Korea, United States, and Germany
- Top patent assignees are dominated by East Asian manufacturers
- Promising alternative technologies: absorption, magnetic & thermoelectric




Contents lists available at ScienceDirect

Journal of Cleaner Production

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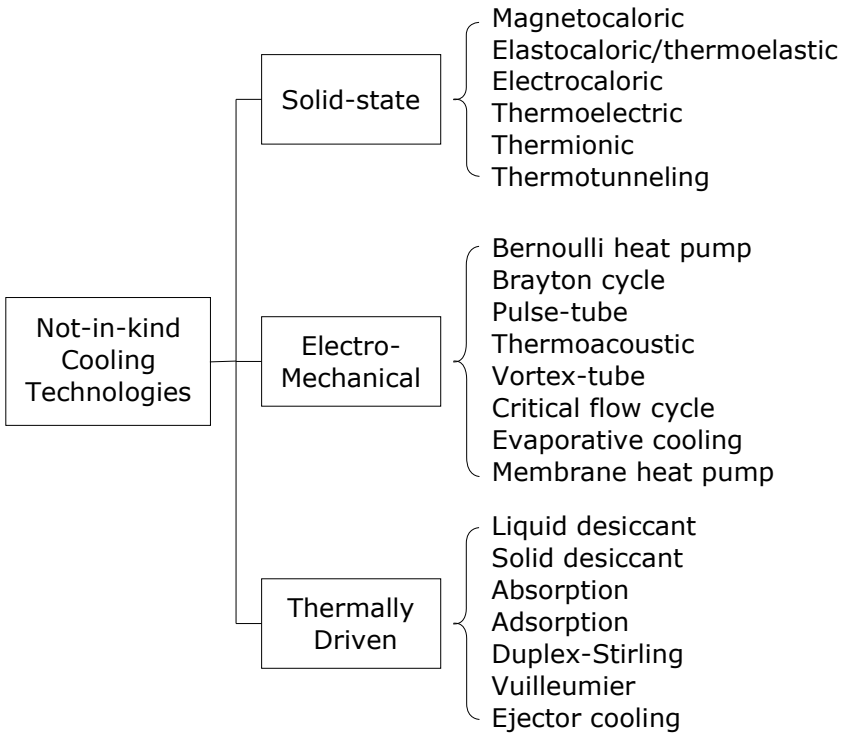
Patent landscape of not-in-kind active cooling technologies between 1998 and 2017

Renaldi Renaldi [a, c, *], Nicole D. Miranda [a, c], Radhika Khosla [b, c], Malcolm D. McCulloch [a, c]

ARTICLE INFO

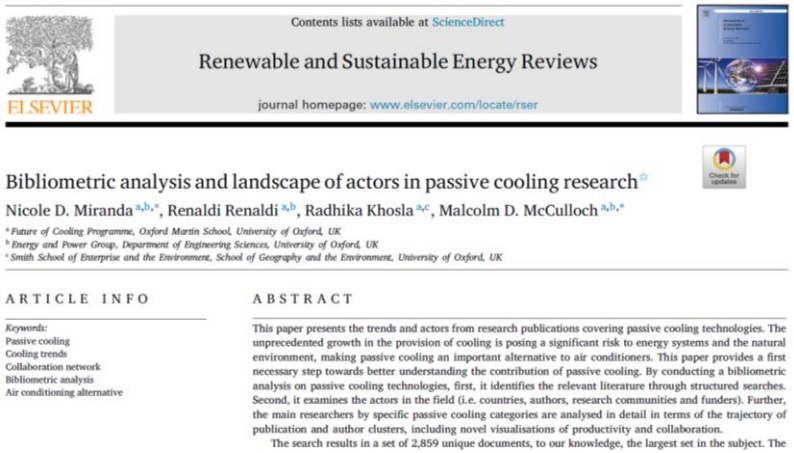
ABSTRACT

The rise in global cooling demand will have significant impacts on our efforts to limit climate change and foster sustainable development. Minimising these impacts requires further development of active cooling technologies, starting with an examination of existing technologies and their characteristics. This paper provides an overview of active cooling technologies using a patent landscape based on patent



Potential of passive cooling

- Much less research and development than active (AC) cooling
  - heat-gain prevention, heat-gain modulation, heat dissipation
- Top five countries: US, China, UK, Italy, India
- High potential for further collaboration
- Dominant technology: Ventilation
- Emerging technology: Radiative cooling



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Bibliometric analysis and landscape of actors in passive cooling research☆

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Keywords:
Passive cooling
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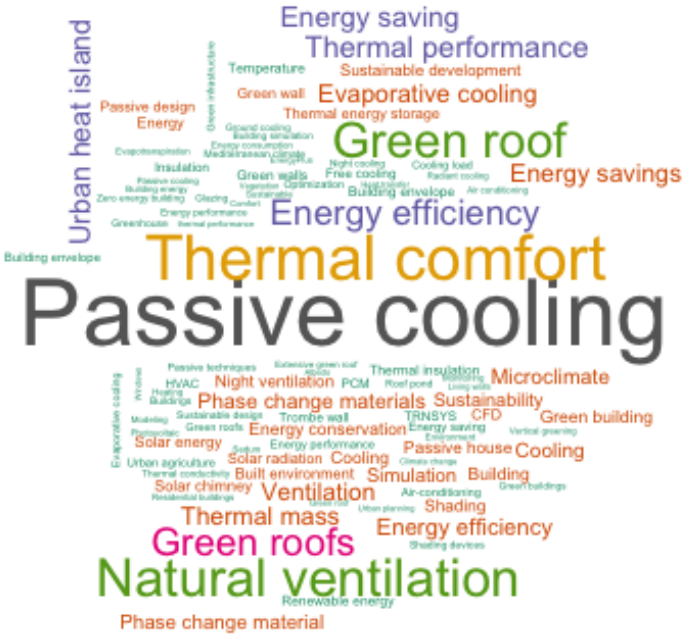
Air conditioning alternative

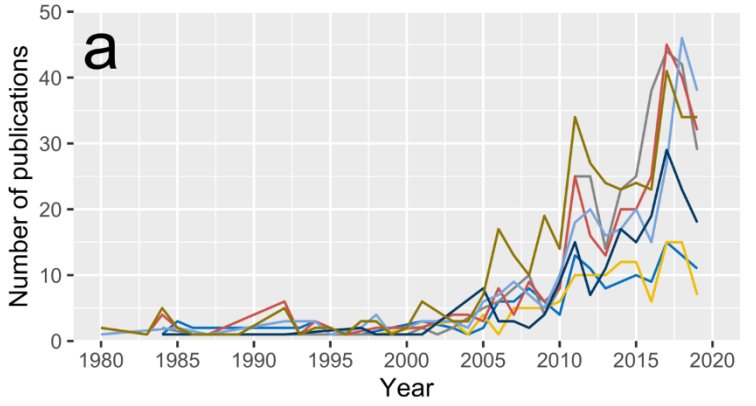
ABSTRACT

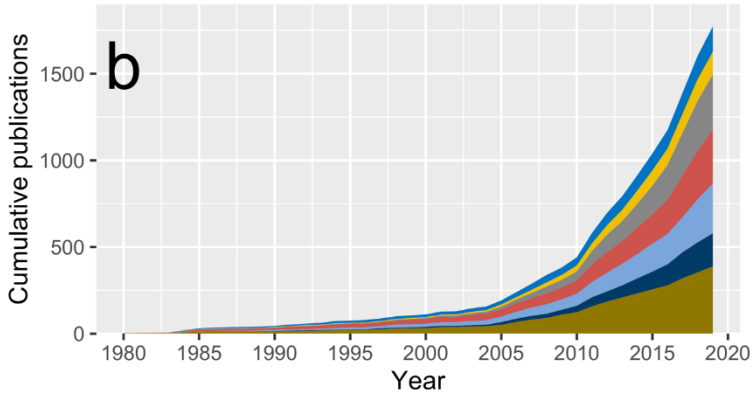
This paper presents the trends and actors from research publications covering passive cooling technologies. The unprecedented growth in the provision of cooling is posing a significant risk to energy systems and the natural environment, making passive cooling an important alternative to air conditioners. This paper provides a first necessary step towards better understanding the contribution of passive cooling. By conducting a bibliometric analysis on passive cooling technologies, first, it identifies the relevant literature through structured searches. Second, it examines the actors in the field (i.e. countries, authors, research communities and funders). Further, the main researchers by specific passive cooling categories are analysed in detail in terms of the trajectory of publication and author clusters, including novel visualisations of productivity and collaboration.

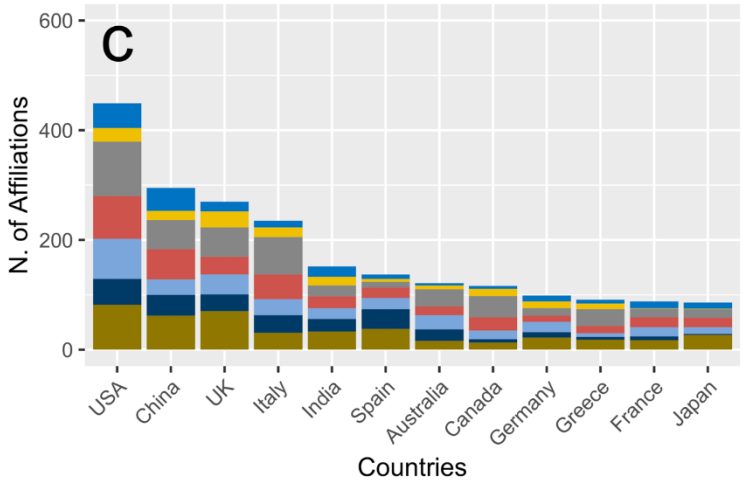
The search results in a set of 2,859 unique documents, to our knowledge, the largest set in the subject. The



Keywords in the literature

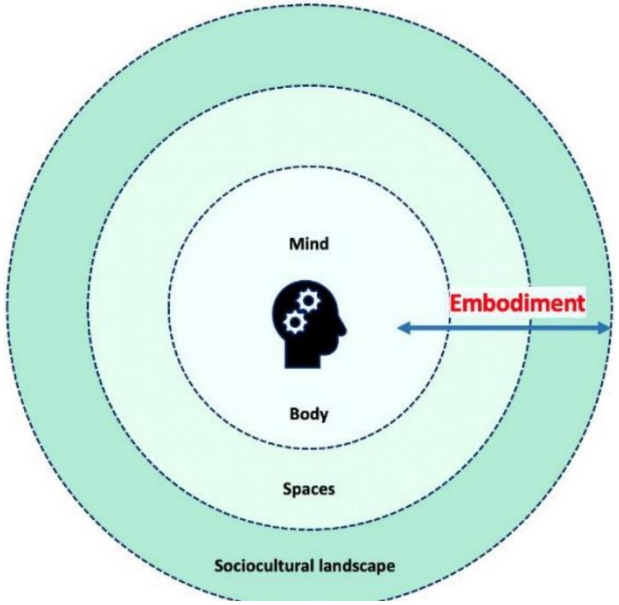


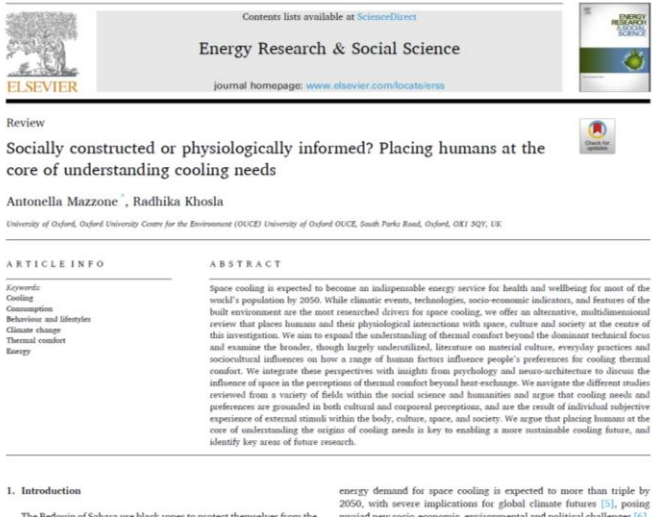




Placing humans at the core of understanding cooling needs

- Cooling needs are informed not only by temperature but also by architecture, design, colours, light intensity, food, drinks, local culture and society, and emotions
- Social construction of 'comfort' and the need for cooling charged with ideas and perceptions of modernity and progress (materially executed by building industries, technology producers, media)
  - Ownership of AC was prerogative sine qua non in the US
- Varied behavioural and cultural approaches to cooling
  - E.g., clothing, diet, lifestyles, and vernacular architecture influence thermal comfort differently in diverse geographies

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Review

Socially constructed or physiologically informed? Placing humans at the core of understanding cooling needs

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ARTICLE INFO

Keywords:
Cooling
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Behaviour and lifestyles
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Thermal comfort
Energy

ABSTRACT

Space cooling is expected to become an indispensable energy service for health and wellbeing for most of the world's population by 2050. While climatic events, technologies, socio-economic indicators, and features of the built environment are the most researched drivers for space cooling, we offer an alternative, multidimensional review that places humans and their physiological interactions with space, culture and society at the centre of this investigation. We aim to expand the understanding of thermal comfort beyond the dominant technical focus and examine the broader, though largely underutilized, literature on material culture, everyday practices and sociocultural influences on how a range of human factors influence people's preferences for cooling thermal comfort. We integrate these perspectives with insights from psychology and neuro-architecture to discuss the influence of space in the perceptions of thermal comfort beyond heat-exchange. We navigate the different studies reviewed from a variety of fields within the social science and humanities and argue that cooling needs and preferences are grounded in both cultural and corporeal perceptions, and are the result of individual subjective experience of external stimuli within the body, culture, space, and society. We argue that placing humans at the core of understanding the origins of cooling needs is key to enabling a more sustainable cooling future, and identify key areas of future research.

1. Introduction

energy demand for space cooling is expected to more than triple by 2050, with severe implications for global climate futures [5], posing

Change in CDDs for 1.5°C and 2.0°C (Median)

Joint work with David Wallom at OeRC

CDD baseline temperature = 21°C

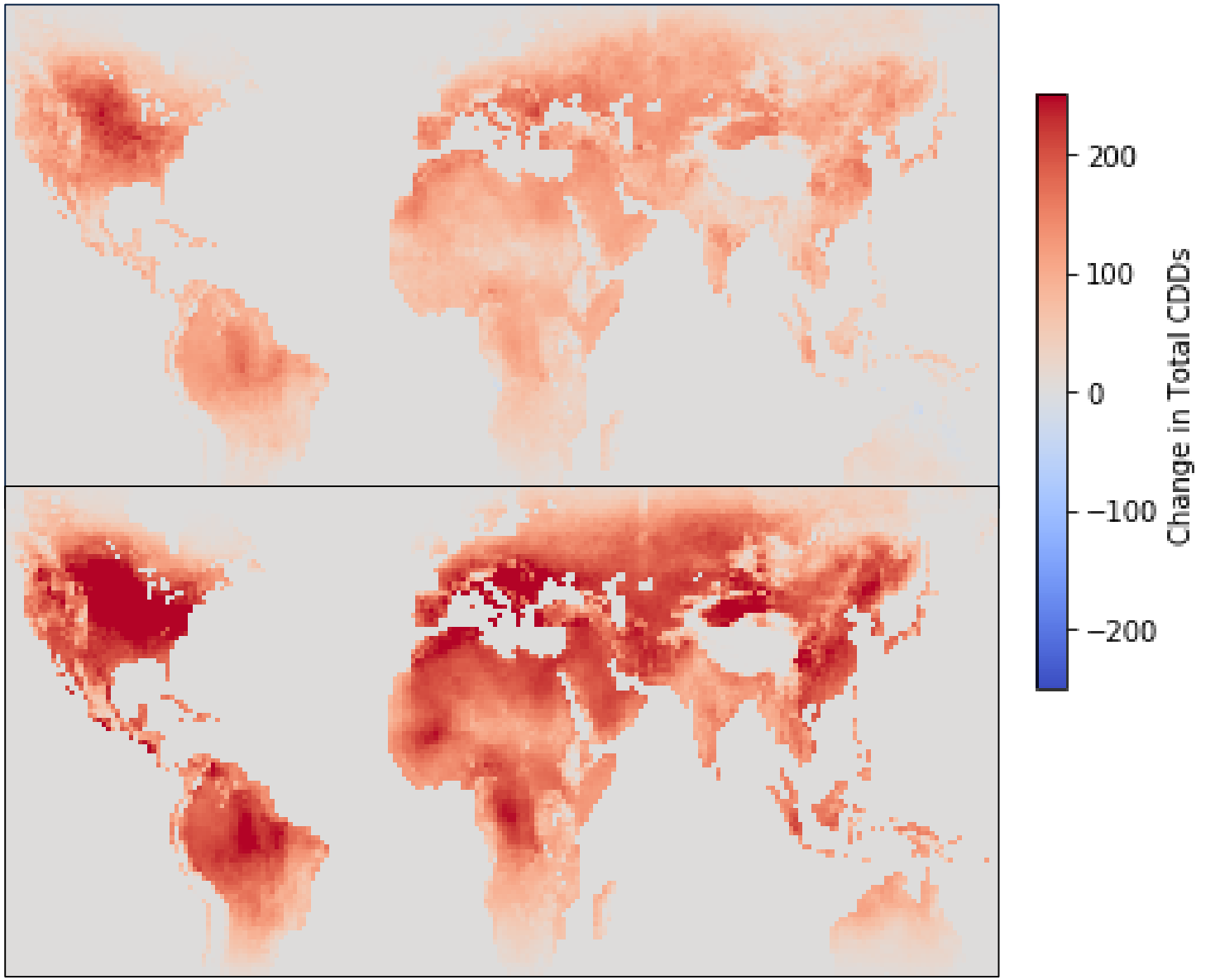
Median and 90th percentile seasonal total CDDs based on ~500 runs

Temporal resolution: 6 hourly. Results for June to September (122 days)

HADAM4 climate model with spatial resolution: 0.55 x 0.833 degrees

Recent historical based on years 2006-2015

Preliminary results from ~500 runs



FUTURE OF COOLING

Thank you

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Malcolm McCulloch, Rafael Perera-Salazar, Caitlin McElroy, Nicole Miranda, Francois Cohen, Antonella Mazzone, Philipp Trotter, Anant Jani, Giovani Palafox-Alcantar, Patrick Fahr, Jesús Lizana, Renaldi Renaldi

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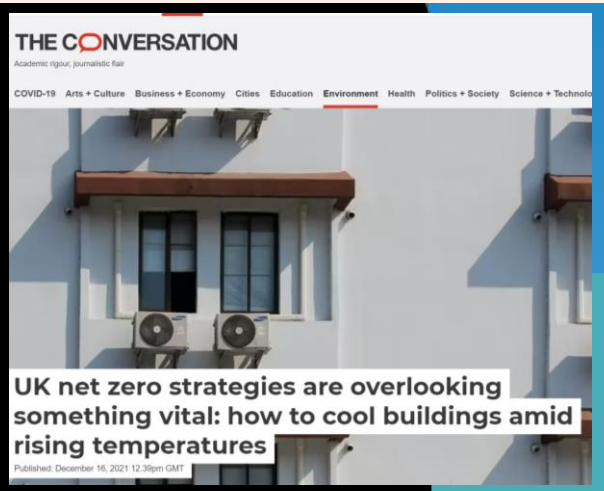
Indian demand for air-conditioning heats up climate fears

Growing energy consumption has researchers looking for more environmentally-friendly methods to keep cool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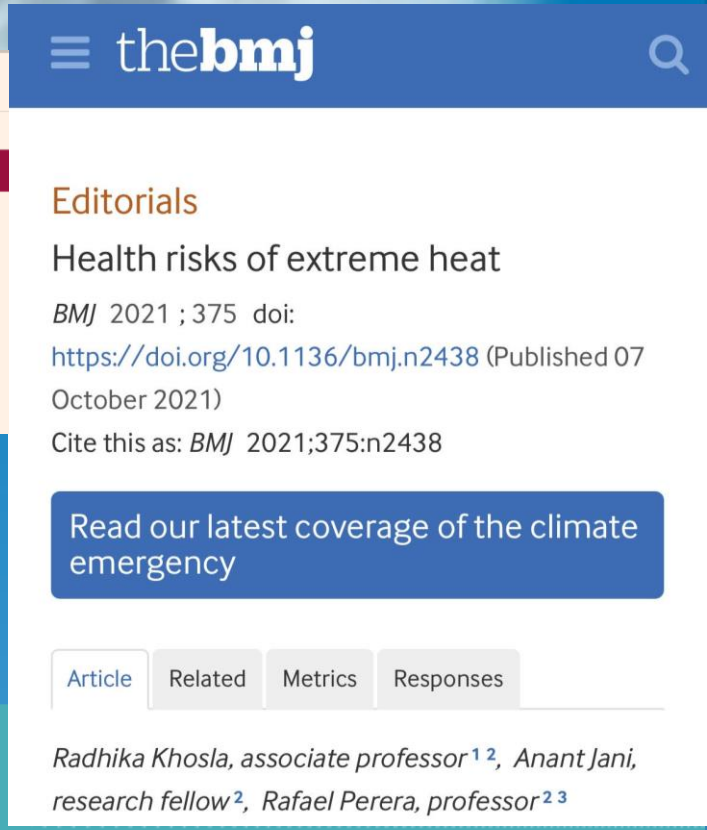
Published: December 16, 2021 12.39pm GMT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Editorials

Health risks of extreme heat

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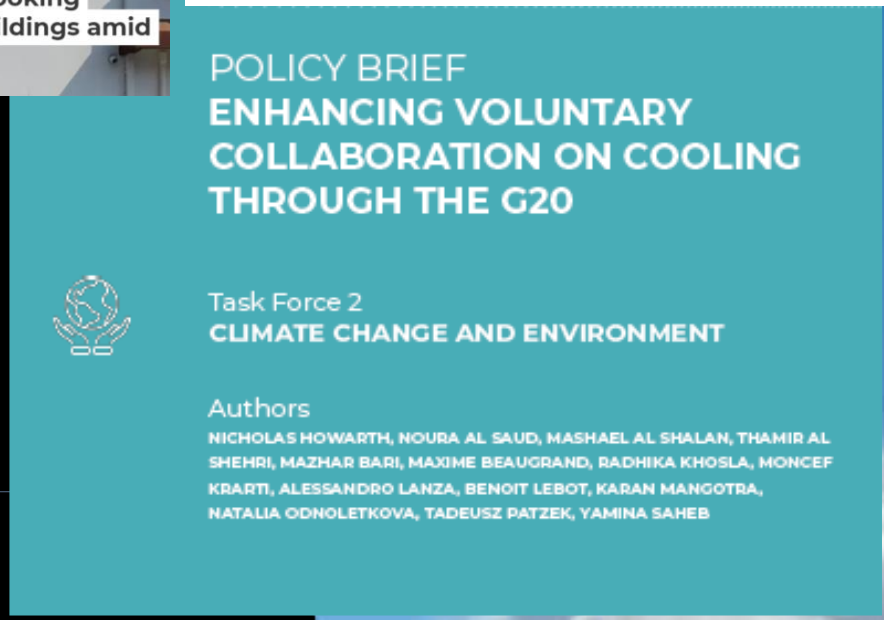
POLICY BRIEF

ENHANCING VOLUNTARY COLLABORATION ON COOLING THROUGH THE G20

Task Force 2
CLIMATE CHANGE AND ENVIRONMENT

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