THE IMPACT OF CLIMATE CHANGE ON HUMAN HEALTH AND HEALTH SYSTEMS: BRIDGING RESEARCH AND ACTIONS FOR A SUSTAINABLE FUTURE

RESEARCH EVIDENCE FROM THE OBSERVATORY ON THE FUTURE OF HEALTHCARE, AUSTRALIAN INSTITUTE OF HEALTH INNOVATION

MACQUARIE University
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OFOH
OBSERVATORY ON THE FUTURE OF HEALTHCARE

The Australian Institute of Health Innovation

The Australian Institute of Health Innovation (AIHI) is a research-intensive institute located at Macquarie University, Sydney with over 300 staff, students and associated and visiting personnel. Proudly supported by the vibrant and rapidly growing Faculty of Medicine, Health and Human Sciences, the Institute conducts world-class research to catalyse performance improvement in healthcare services and systems in Australia and internationally. As part of our mission, we strive to **Heal | Learn | Discover**.

About the Observatory on the Future of HealthCare

The Observatory on the Future of Healthcare (OFOH) is a flagship initiative within AIHI. OFOH brings together key researchers, ideas, frameworks, models and studies conducted at AIHI and beyond to deeply understand how to decarbonise healthcare and adapt to climate-induced threats and opportunities facing human health and systems.

The team

OFOH comprises 15 researchers with expertise ranging across Climate Change, Human Health, Health Systems, Informatics, Big Data, Medicine, Nursing, Allied Health, Psychology, Patient Safety, Systems Improvement, Complexity Science, Implementation Science, and Change Management. Appendix 1 contains a listing of the research team.

This document

This document contains a short synthesis of some of our recent work on climate change and human health. To cite this paper:

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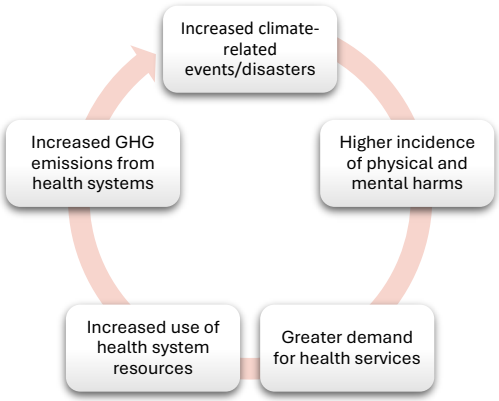
Executive Summary

Healthcare systems face a complex, bi-directional challenge posed by climate change: they significantly contribute to greenhouse gas (GHG) emissions while also being on the front lines of addressing the health impacts of climate change. The healthcare sector is under immense pressure from increasing demands, technological advancements, and workforce shortages, making it essential to both adapt to and mitigate climate-related harm.

Climate change adversely affects human health through extreme weather events—such as cyclones, heatwaves, floods, and droughts—and the rise of infectious and vector-borne diseases. It worsens chronic conditions like cardiovascular and respiratory diseases and increases the prevalence of climate-related health issues, such as heat stroke. Beyond physical health, climate change is linked to rising mental health challenges, with one in eight people globally experiencing mental health conditions, many exacerbated by environmental stressors.

The interconnectedness of healthcare and climate change reveals a critical dilemma: healthcare activities generate substantial GHG emissions—approximately 4.4% of global emissions—while the health impacts of climate change drive increased healthcare utilisation. If the healthcare sector were a country, it would rank as the fifth largest emitter of GHGs. Globally, healthcare contributes more GHGs than aviation and the maritime industry combined.



Source: Braithwaite et al, 2024. *BMJ.*

In response, the Observatory on the Future of Healthcare (OFOH) is spearheading research to develop low-carbon, climate-resilient healthcare systems. Appendix 2 provides a briefing on a National Roundtable we convened to develop Australian research capacity in this area.

OFOH produces best practice studies, systematic reviews, and evidence-based solutions to address these pressing challenges. A selection of our findings is included below.

The goal for healthcare is to move toward systems that are affordable, equitable, and cost effective; systems that improve health outcomes and minimise environmental impact—via both mitigation and decarbonisation. They are also systems that are sufficiently resilient and adaptable to be able to cope with future exigencies. Our OFOH strategy is to provide the evidence to support global efforts.

Word cloud containing the key words in the OFOH's work was produced using WordArt.com and curated from the following sources: Braithwaite et al, 2023, *BMJ*; Braithwaite et al, 2024, *Nature Clim Chang*; Braithwaite et al, 2024, *BMJ*; Naru et al, 2024, *Prog Disaster Sci* ; Smith et al, 2024, *BMC Med*; Spanos et al, 2024, *BMC Health Serv Res* ; Zurynski et al, 2023, *Int J Health Plann Mgmt*.

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Research highlights

In the last ten years, OFOH and AIHI have received multiple National Health and Medical Research Council (NHMRC) and Medical Research Future Fund (MRFF) grants and published over 100 articles, books and book chapters on how to create sustainable health systems. Here, we digest some of the most relevant contributions at the intersection of climate change, health systems and human health.

- **Analysing health system capacity and preparedness for climate change** (Braithwaite et al, 2024)
  We analysed 129 articles to assess the current and projected coping capacity of health systems under climate change. This article develops a new model of seven activities to which policy makers, clinicians, patients and agencies need to attend to ensure the future-proofing of their health system. Published in leading journal *Nature Climate Change* and featured in an Editorial commentary in the journal.
- **Strategies and tactics to reduce the impact of healthcare on climate change: systematic review** (Braithwaite et al, 2024)
  We reviewed 205 articles on mitigation strategies and tactics in healthcare to develop a framework that supports the decarbonisation of healthcare systems. Nine strategies and tactics for decarbonising healthcare were distilled from the literature. This article was published in the *British Medical Journal* and was featured as an *Editor's Choice*.
- **Learning Health System 2.0 (LHS 2.0)** (Braithwaite et al, 2023)
  The Learning Health System 2.0 model developed by the OFOH team provides a response to future-proofing the health system. Modified from the original 2007 Institute of Medicine (IoM) model, the LHS 2.0 model has garnered widespread interest and support. OFOH has published over 18 refereed contributions and presented at over 45 seminars, conferences and workshop in 15 different countries on this Idea. Work continues, developed both by the OFOH team and colleagues in Europe and the US.
- **Tackling climate change: the pivotal role of clinicians** (Braithwaite et al, 2023)
  Clinicians on the frontlines have significant knowledge of their own practices, alongside a deep understanding of healthcare's carbon footprint. They are already making major contributions to reducing GHGs and supporting healthcare to be more adaptive. Going further, they can advocate for legislative change, influence healthcare leaders, promote preventative health care, and reduce the provision of low value care as key examples of their role in helping healthcare become more climate change-responsive.
- **The three numbers you need to know about healthcare: the 60-30-10 Challenge** (Braithwaite, Glasziou & Westbrook, 2020)
  This contribution is an original re-specification of a problem evidenced by many large empirical US, English and Australian studies. On average 60% of care is in line with evidence and guidelines; 30% of care is estimated to be waste; and 10% of healthcare encounters result in an adverse event or serious harm to a patient. A highly cited and influential article, it offers major insights into the key metrics challenging health systems and has been utilised globally including by the OECD and the UK's Health Foundation.

- **The Routledge Handbook on Climate Change and Health System Sustainability** (eds. Braithwaite, Zurynski & Smith, 2024)
  This Handbook from leading publisher Routledge provides an in-depth exploration of the interrelationship among human health, climate change, and healthcare systems. The compendium unites a diverse array of 75 innovative environmental and health researchers, policymakers, leaders, managers, clinicians, patients, and health industry executives to elucidate the status of and prospects for sustainable healthcare systems. It is particularly relevant to anyone interested in the fields of climate and health systems. As well as addressing issues facing high income countries, the book includes authors drawn from low- and middle-income countries, e.g., from Africa and South-East Asia. For a summary of the book and its perspectives: see Appendix 3.
- **Turbulence health systems: engineering a rapidly adaptive health system for times of crisis** (Coiera & Braithwaite, 2021)
  We define a *turbulence health system* as one that has been fashioned to operate across multiple conditions and has the flexibility and capacity to reconfigure itself in meeting its multiple demands and disruptions. The ability to deal with future shocks such as pandemics and climate change becomes a crucial precondition for successful system performance.
- **Digital health for climate change mitigation and response: a scoping review** (Rahimi-Ardabili et al, 2022)
  This paper systematically examined 142 publications at the intersection of digital health and climate change, categorised into three domains: mitigation, infectious disease management, and management of risks to environmental health. The conclusion was that much more research is required to enable digital health to realise its contribution in tackling climate change.
- **Learning health systems on the front lines to strengthen care against future pandemics and climate change: a rapid review** (Spanos et al, 2024)
  Of the 37 articles digested in this review, focussed on front-line care in emergency department and primary care settings and their role in adopting LHS 2.0 principles, most centred on primary care. We argued that developing LHSs which are effective in processing information and predicting future challenges can play a central role in future-proofing the health system against current and new threats to healthcare sustainability.
- **Bolstering health systems to cope with the impacts of climate change events: a review of the evidence on workforce planning, upskilling, and capacity building** (Zurynski et al, 2024)
  Here, we weighed the evidence about the capacity of the health workforce to combat climate change-induced sequelae. The 60 studies directed attention to the impact of climate events on the workforce, and workforce responses to climate events. Over time the health workforce will come under increasing pressure as demands and climate events occur more frequently. Focussing on the workforce's expansion, upskilling and education, and providing it with sufficient support will become increasingly important to ensure a continuously sustainable and improving system.

Selected research evidence published in leading peer-reviewed journals and links to the work

1. Braithwaite, J., Glasziou, P., and Westbrook, J. (2020). The three numbers you need to know about healthcare: the 60-30-10 challenge. *BMC Medicine,* 18:102. https://doi.org/10.1186/s12916-020-01563-4

2. Braithwaite, J., Leask, E., Smith, C.L., Dammery, G., Brooke-Cowden, K., Carrigan, A., McQuillan, E., Ehrenfeld, L., Coiera, E., Westbrook, J., and Zurynski, Y. (2024). Analysing health system capacity and preparedness for climate change. *Nature Climate Change*, 14:536-546. https://doi.org/10.1038/s41558-024-01994-4

3. Braithwaite, J., Pichumani, A., and Crowley, P. (2023). Tackling climate change: the pivotal role of clinicians. *BMJ,* 382:e076963. https://doi.org/10.1136/bmj-2023-076963

4. Braithwaite, J., Smith, C. L., Leask, E., Wijekulasuriya, S., Brooke-Cowden, K., Fisher, G., Patel, R., Pagano, L., Rahimi-Ardabili, H., Spanos, S., Rojas, C., Partington, A., McQuillan, E., Dammery, G., Carrigan, A., Ehrenfeld, L., Coiera, E., Westbrook, J., and Zurynski, Y. (2024). Strategies and tactics by which to reduce healthcare's impact on climate change: systematic review. *BMJ. 387*:e081284. https://doi.org/10.1136/bmj-2024-081284

5. Braithwaite, J., Tran, Y., Ellis, L. A., and Westbrook, J. (2020). The 40 health systems, COVID-19 (40HS, C-19) study. *International Journal for Quality in Health Care*, 33:1-7. https://doi.org/10.1093/intqhc/mzaa113

6. Coiera, E. and Braithwaite, J. (2021). Turbulence health systems: engineering a rapidly adaptive health system for times of crisis. *BMJ Health & Care Informatics,* 28:e100363. https://doi.org/10.1136/bmjhci-2021-100363

7. Coiera, E. and Magrabi, F. (2022). What did you do to avoid the climate disaster? A call to arms for health informatics. *Journal of the American Medical Informatics Association*, 29:1997-9. https://doi.org/10.1093/jamia/ocac185

8. Dammery, G., Ellis, L. A., Churruca, K., Mahadeva, J., Lopez, D., Carrigan, A., Halim, N., Willcock, S., and Braithwaite J. (2023). The journey to a learning health system in primary care: a qualitative case study utilising an embedded research approach. *BMC Primary Care*, 24:22. https://doi.org/10.1186/s12875-022-01955-w

9. Naru, F. S., Churruca, K., Long, J. C., and Sarkies, M. (2024) Disaster preparedness in Australian hospitals: A cross-sectional survey. *Progress in Disaster Science*, 24:100369. https://doi.org/10.1016/j.pdisas.2024.100369.

10. Fry, J., Bone, A., Kanemoto, K., Smith, C. L., and Watts, N. (2024). Environmental footprinting in health care: a primer. *Medical Journal of Australia*. https://doi.org/10.5694/mja2.52481

11. Rahimi-Ardabili, H., Magrabi, F., and Coiera, E. (2022). Digital health for climate change mitigation and response: a scoping review. *Journal of the American Medical Informatics Association*, 29:2140-52. https://doi.org/10.1093/jamia/ocac134

12. Smaggus, A., Long, J. C., Ellis, L. A., Clay-Williams, R., and Braithwaite, J. (2022). Government actions and their relation to resilience in healthcare during the COVID-19 pandemic in New South Wales, Australia and Ontario, Canada. *International Journal of Health Policy and Management,* 11(9):1682-1694. https://doi.org/10.34172/ijhpm.2021.67

13. Smith, C. L., Fisher, G., Dharmayani, P. N. A., Wijekulasuriya, S., Ellis, L. A., Spanos, S., Dammery, G., Zurynski, Y., and Braithwaite, J. (2024). Progress with the Learning Health System 2.0: a rapid review of Learning Health Systems' responses to pandemics and climate change. *BMC Medicine*, 22:131. https://doi.org/10.1186/s12916-024-03345-8

14. Smith, C. L., Rojas, C., Zurynski, Y., Partington, A., and Braithwaite, J. (2024). What Australia must do to create a climate-responsive health system. *Internal Medical Journal*. https://doi.org/10.1111/imj.16528

15. Smith, C. L., Zurynski, Y., and Braithwaite, J. (2022). We can't mitigate what we don't monitor: using informatics to measure and improve healthcare systems' climate impact and environmental footprint. *Journal of the American Medical Informatics Association*, 29:2168-73. https://doi.org/10.1093/jamia/ocac113

16. Spanos, S., Dammery, G., Pagano, L., Ellis, L. A., Fisher, G., Smith, C. L., Foo, D., and Braithwaite, J. (2024). Learning health systems on the front lines to strengthen care against future pandemics and climate change: a rapid review. *BMC Health Services Research,* 24. https://doi.org/10.1186/s12913-024-11295-3

17. Zurynski, Y., Fisher, G., Wijekulasuriya, S., Leask, E., Dharmayani, P.N.A., Ellis, L.A., Smith, C.L., and Braithwaite, J. (2024). Bolstering health systems to cope with the impacts of climate change events: a review of the evidence on workforce planning, upskilling, and capacity building. *International Journal of Health Planning and Management*, 39(3):781-805. https://doi.org/10.1002/hpm.3769

18. Zurynski, Y., Herkes-Deane, J., Holt, J., McPherson, E., Lamprell, G., Dammery, G., Meulenbroeks, I., Halim, N., and Braithwaite, J. (2022). How can the healthcare system deliver sustainable performance? A scoping review. *BMJ Open,* 12(5):e05920. https://doi.org/10.1136/bmjopen-2021-059207

Research evidence shared through selected keynotes, conference presentations and invited talks

Event	Presentation
Big History Anthropocene Conference: A Transdisciplinary Exploration	Karoly, D., Braithwaite, J., and Baker, D. (2015) Panel discussion: climate change, health, & population. *Big History Anthropocene Conference: A Transdisciplinary Exploration*. Macquarie University, Sydney, Australia, December 11.
Tedx Macquarie University	Braithwaite, J. (2019) Have we reached a turning point, a breaking point or a vanishing point? Speaker at *Tedx Macquarie University*. Sydney, Australia, September 21.
AIHI Webinar	Hughes, L., and Braithwaite, J. (2021) Professor Lesley Hughes asks: Climate change: how worried should we be? *AIHI Webinar*. Virtual, August 10. https://www.youtube.com/watch?v=v0crC1snidw
Human Health, and Healthcare System Sustainability Webinar	Braithwaite, J. (2021) Creating more sustainable healthcare systems. *Exploring the Nexus of Climate Change, Human Health, and Healthcare System Sustainability Webinar*. Sydney, Australia, Virtual, December 2.
United Nations General Assembly Science Summit (UNGA77)	Braithwaite, J. (2022) 60:30:10, Learning Health Systems and the future of healthcare to 2030. *Presentation at the United Nations General Assembly Science Summit (UNGA77)*. Virtual, New York, September 26-27.
38th International Society for Quality in Health Care Conference (ISQua 2022)	Braithwaite, J., Buchbinder, R., Capon, T., Smith, C. L., and Zurynski, Y. (2022) Climate change and health systems strengthening: How best can we prepare? *38th International Society for Quality in Health Care Conference (ISQua 2022)*. Brisbane, Australia, October 17-20.
38th International Society for Quality in Health Care Conference (ISQua 2022)	Smith, C.L., Braithwaite, J., Ellis, L.A., Dammery, G., and Zurynski, Y. (2022) A learning health system: At the heart of climate change and its effects on human health and health systems. *38th International Society for Quality in Health Care Conference (ISQua 2022)*. Brisbane, Australia, October 17-20.
United Nations General Assembly Science Summit Digital Health Plenary	Curley, M., Kirrane, D., Crooks, G., DeAngelis, D., Matthies, H., Zatloukal, K., Krishnan, K.A., Boyle, G., Shaw, J., Graham, T., Braithwaite, J., Teisberg, E., Columbo, F., Cahana, A., and Gurel, O. (2022) The Digital Transformation for Healthcare – Stay Left, Shift Left: A paradigm, policy, platform and prescription for wellness and better health. *United Nations General Assembly Science Summit Digital Health Plenary*. September/October.

Participation as Expert evaluator on panel discussion at 2023 Horizon Europe Health Grant Panel	Braithwaite, J. (2023) Environmentally sustainable and climate neutral health and care systems. *Participation as Expert evaluator on panel discussion at 2023 Horizon Europe Health Grant Panel.* Brussels, Belgium, June 5-9.
NHMRC Partnership Centre for Health Systems Sustainability Showcase	Zurynski, Y., and Braithwaite, J. (2023) Observatory on Health System Sustainability. *Presentation at the NHMRC Partnership Centre for Health Systems Sustainability Showcase.* Macquarie University. Sydney, Australia, June 16.
39th International Society for Quality in Health Care Conference (ISQua 2023)	Braithwaite, J., and Vyas, A. (2023) Towards a new ISQua Green Paper on high quality, environmentally sustainable healthcare. *Workshop at the 39th International Society for Quality in Health Care Conference (ISQua 2023).* Seoul, South Korea, August 28-30.
39th International Society for Quality in Health Care Conference (ISQua 2023)	Dammery, G., Leask, E., Carrigan, A., and Braithwaite, J. (2023) Climate change is coming, are health systems prepared? Findings from a systematic review. *Abstract at the 39th International Society for Quality in Health Care Conference (ISQua 2023).* Seoul, South Korea, August 28-30.
39th International Society for Quality in Health Care Conference (ISQua 2023	Dammery, G., Leask, E., Carrigan, A., and Braithwaite, J. (2023) Climate change is coming, are health systems prepared? Findings from a systematic review. *Short oral at the 39th International Society for Quality in Health Care Conference (ISQua 2023).* Seoul, South Korea, August 28-30.
Health Insurance Review and Assessment Service (HIRA) International Symposium	Braithwaite, J. (2023) Can we make a better health system by 2030? Fortifying future healthcare system through integrated healthcare. *Keynote at Health Insurance Review and Assessment Service (HIRA) International Symposium*. Seoul, South Korea, August 31.
Climate and Health Alliance (CAHA) Greening the Healthcare Sector Forum	Smith, C.L., Dammery, G., Zurynski, Y., and Braithwaite, J. (2023) Greening healthcare: unpacking the toolkit for decarbonising healthcare systems - a systematic review. *Presentation at Climate and Health Alliance (CAHA) Greening the Healthcare Sector Forum*. Fiona Stanley Hospital, Perth, Australia, September 14-15.
8th annual EnCouRage Research Symposium	Leask, E., Ellis, L.A., Dammery, G., and Braithwaite, J. (2023) Climate change and the increased burden on mental health services: the importance of workforce preparedness. *Poster presentation at the 8th annual EnCouRage Research Symposium*. Macquarie University, Sydney, Australia, September 25.
United Nations General Assembly Digital Health Symposium (UNGA 78)	Braithwaite, J. (2023) Leading the digital revolution: Stay Left, Shift Left. *Presentation at the United Nations General Assembly Digital Health Symposium (UNGA 78)*. New York, New York, September 26.

Nations General Assembly Digital Health Symposium (UNGA 78)	Braithwaite, J. (2023) The three numbers you need to know about healthcare: Moving into the digital future. *Presentation at the United Nations General Assembly Digital Health Symposium (UNGA 78)*. New York, New York, September 27.
OECD Workshop on Climate Change and Health	Braithwaite, J. (2023) The healthcare implications of climate change. *Keynote virtual presentation at the OECD Workshop on Climate Change and Health*. Paris, France, October 4.
Te Tāhū Hauora – Health Quality & Safety Commission Quality Improvement Scientific Symposium 2023	Braithwaite, J. (2023) The Future of Healthcare to 2030: The Aotearoa New Zealand context. *Keynote presentation at Te Tāhū Hauora – Health Quality & Safety Commission Quality Improvement Scientific Symposium 2023*. Holiday Inn Auckland Airport, Māngere, Auckland, New Zealand, November 8.
Presentation to the County Governor; Sustainability and Sustainable Healthcare Services. Stavanger, Norway	Braithwaite, J. (2023) Preparing for climate change and pandemics: Sustainable ecosystems and healthcare by 2030. *Presentation to the County Governor; Sustainability and Sustainable Healthcare Services*. Stavanger, Norway, November 20.
Healthcare Climate Change Conference at Jönköping University.	Braithwaite, J. (2024) Healthcare systems and climate change. *Keynote Presentation at the Healthcare Climate Change Conference at Jönköping University*. Jönköping, Sweden, February 28.
The Australian Council of Learned Academies (ACOLA) Parliamentary Library Seminar.	Braithwaite, J. (2024) Healthcare: the sustainability of Australia's health system? (Are we spending money on the right types of health care?). *Keynote for the Australian Council of Learned Academies (ACOLA) Parliamentary Library Seminar*. Canberra, Australia, Virtual, April 10.
The Australian Council of Learned Academies (ACOLA) and Department of Health and Aged Care	Braithwaite, J. (2024) Future-proofing healthcare. *Keynote for the Australian Council of Learned Academies (ACOLA) and Department of Health and Aged Care*. Canberra, Australia, Virtual, April 29.
The World Bank	Braithwaite, J. (2024) The health innovation and health reform arenas: Use of digital technology and data. *Keynote at the World Bank*. Sydney, Australia, May 16.
Academy Health's 2024 Annual Research Meeting (ARM)	Braithwaite, J., Fisher, G., Ellis, L.A., Smith, C.L., Spanos, S., Long, J., Churruca, K., Pagano, L., and Zurynski, Y. (2024) Moving to a Learning Health System 2.0 (LHS 2.0) Model: Applications to the US and OECD Health systems. *Academy Health's 2024 Annual Research Meeting (ARM)*. Baltimore, United States of America, June 29-July 2.

Academy Health's 2024 Annual Research Meeting (ARM)	Smith, C. L., Rojas, C., Zurynski, Y., Partington, A., Ellis, L.A., Dammery, G., Fisher, G., Spanos, S., Long, J.C., Churruca, K., and Braithwaite, J. (2024) Creating low-carbon, climate-resilient health systems: what frameworks, policies, and standards should we apply? *Academy Health's 2024 Annual Research Meeting (ARM).* Baltimore, United States of America, June 29-July 2.
MQ Health seminar series	Braithwaite, J. (2024) The impact of climate change on healthcare and human health. *Keynote at MQ Health seminar series*. Sydney, Australia, July 11.
Harvard University Safety, Quality, Informatics and Leadership Workshop	Braithwaite, J. (2024) Climate change and health and safety. *Harvard University Safety, Quality, Informatics and Leadership Workshop 1*. Boston, Massachusetts USA, Virtual, July 17.
40th International Society for Quality in Health Care Conference (ISQua 2024)	Pagano, L., Spanos, S., Dammery, G., Ellis, L. A., Smith, C. L., Fisher, G., Foo, D., and Braithwaite, J. (2024) Health for people and planet: building bridges to a sustainable future. *International Society for Quality in Health Care Conference (ISQua 2024*). Istanbul, Türkiye, September 24-27.
40th International Society for Quality in Health Care Conference (ISQua 2024)	Braithwaite, J. (Chair), Zurynski, Y., Nelson, E., Pichumani, A., Alahdab, H., Ellis, L. A., Smith, K.L., Fisher, G., McDonald, P., Devkaran, S., Dowdy, S., Foley, T., Gilman, S., Habermann, E., Harwood, K., Verheij, R., Phillips, J. R., Rubin, J., Spanos, S., van der Wees, P., Yao, X., and Bos, I.(2024) Next generation learning health systems. *The 40th International Society for Quality in Health Care Conference (ISQua 2024).* Istanbul, Türkiye, September 24-27.
40th International Society for Quality in Health Care Conference (ISQua 2024)	Braithwaite, J. (Chair), Smith, K. L., Ellis, L. A., and Zurynski, Y. (2024) Decarbonising healthcare systems: We all have a role to play. *The 40th International Society for Quality in Health Care Conference (ISQua 2024).* Istanbul, Türkiye, September 24-27.
40th International Society for Quality in Health Care Conference (ISQua 2024)	Fisher, G., Ellis, L. A., Saba, M., and Braithwaite, J. (2024) What's in a Learning Health System? A rapid review of emerging definitions, models, and frameworks. *The 40th International Society for Quality in Health Care Conference (ISQua 2024*). Istanbul, Türkiye, September 24-27.
40th International Society for Quality in Health Care Conference (ISQua 2024)	Braithwaite, J. (Chair), Sodemann, M., Perlin, J. B., Zurynski, Y., and Ergüder, T. (2024) Action for healthy systems, healthy people and a healthy planet. *The 40th International Society for Quality in Health Care Conference (ISQua 2024).* Istanbul, Türkiye, September 24-27.

Examples of media coverage demonstrating impact

AIHI is committed to disseminating research insights widely to ensure evidence becomes broadly accessible. Here are some selected public-facing examples.

1. Braithwaite, J., Zurynski, Y., Smith, C. L., and Hughes, L. (2021) Climate change, human health, and health care systems. *MJA Insight+*. https://insightplus.mja.com.au/2021/45/climate-change-human-health-and-health-care-systems/
2. Coiera, E. (2022) Can digital health help curb sector's climate impact? *Wild Health*. https://wildhealth.net.au/can-digital-health-help-curb-sectors-climate-impact/
3. Coiera, E. (2022) Telehealth for climate change, the latest on IBM Watson, & hospital billing transparency, *Stat news*. https://www.statnews.com/2022/11/22/health-tech-climate-change-data-hospitals/
4. Smith, C. L., Zurynski, Y., Clay, C., and Braithwaite J. (2023) Measure, monitor and mitigate - the three M's needed to achieve climate resilient, carbon-neutral healthcare systems. *The Health Advocate*. https://issuu.com/aushealthcare/docs/the_health_advocate_-_november_2023/30

Selection of journal articles

The following pages include a snapshot of significant published journal articles. To request a copy of a journal article, please contact Professor Braithwaite at: jeffrey.braithwaite@mq.edu.au

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[2] Sree Renga Hospital, Chengalpattu, India

[3] Health Services Executive, Dublin, Republic of Ireland

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ACTIONS FOR SUSTAINABLE HEALTHCARE

Tackling climate change: the pivotal role of clinicians

Jeffrey Braithwaite, [1] Anuradha Pichumani, [2] Philip Crowley[3]

What you need to know

- Healthcare systems are major emitters of greenhouse gases, but also have to manage increased demand for care as a consequence of the climate crisis
- Key sources of greenhouse gas emissions include energy generated from fossil fuels, running of services, and healthcare supply chains (transport, pharmaceuticals, equipment, and food)
- Reducing greenhouse gas emissions can be achieved through legislation and policy, effective leadership and management, and above all, promoting sustainable practice in front line care

Sources and selection criteria

We searched Medline for articles, and the internet for publicly available reports of policy actions by healthcare services and institutions seeking to limit their greenhouse gas emissions. We also drew on our own expertise.

Every healthcare professional, manager, policymaker, politician, and patient has a role to play in securing net zero carbon emissions in healthcare, and front line clinicians can make a profound difference. This article offers an overview of the carbon footprint of healthcare, as a preview to the BMJ's Actions for Sustainable Healthcare series, which will highlight practical actions clinicians can take to support reaching the net zero goal. Key terms used in this article are defined in box 1.

Box 1: Definitions of key terms[1-8]

- Adaptation: Adjusting to and coping with present or future climate change
- Carbon dioxide equivalents (CO_2eq): A metric derived from converting different types of greenhouse gases (eg, carbon dioxide, methane, nitrous oxide) to one standardised measure
- Carbon footprint: The total amount of greenhouse gases generated by human activity—expressed, for example, per person, or per institution such as a hospital or NHS trust
- Greenhouse gas emissions: Gases that trap heat in the Earth's atmosphere
- Hotspot: A zone or area which represents an intense concentration of greenhouse gas emissions, eg, hospital wards, laboratories, and operating theatres
- Life cycle assessment: A method of estimating the environmental impact generated across the life of a product, process, or service
- Low value care: Clinical treatment or services that provide minimal or no benefit to patients
- Mitigation: Measures to reduce greenhouse gas emissions from the atmosphere
- Net zero: When amounts of greenhouse gases produced and removed from the atmosphere are in balance
- Supply chain: The production flow of products and services to and from a provider—in the case of healthcare, for example, water, consumables, medical equipment, drugs, and food
- Scopes 1, 2, and 3:
  - Scope 1: emissions generated from directly running care services and facilities
  - Scope 2: emissions created through buying and consuming energy
  - Scope 3: emissions caused by the goods, materials and equipment healthcare facilities use and dispose of; including transport and services provided

How large is the carbon footprint of healthcare?

Based on modelling of economic activity and carbon emissions projections, greenhouse gas emissions from healthcare (usually measured as carbon dioxide equivalents, or CO_2eq) account for between 3% and 8.5% of a country's total emissions, depending on the health system, with the average at 4-5%.[4 9] On a global scale, this is the same as the total emissions of the African continent (almost 1.5 billion people across 54 countries).[9 10] Greenhouse gas emissions from healthcare vary depending on the wealth and relative carbon intensity of the country and its electricity grid.[10]

These differences can be considerable. Healthcare in the US, for example, accounts for 8.5% of the nation's carbon footprint in absolute terms and per capita, whereas in England it is less than 4.4% (fig 1).[4 9 -11] While fewer reliable data are available on the emissions generated in lower resource settings, low and middle income countries contribute substantially fewer absolute carbon emissions than high income countries. However, estimates are more uncertain and these countries are sometimes reported to be more carbon intensive per unit of expenditure.[12]

nature climate change

Analysis

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Analysing health system capacity and preparedness for climate change

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Check for updates

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While increasing literature demonstrating the direct and indirect impacts of climate change focuses on health, the capacity and preparedness of healthcare systems to deal with these impacts are less frequently considered. Here we performed a systematic analysis of peer-reviewed and grey literature to assess the current and projected coping capacity for healthcare systems under climate change. Data from the 129 included publications focused broadly on seven topics: workforce, tools and frameworks, infrastructure and urban planning, communication, surge capacity and increased system burden, service interruption and financial costs. Publications were biased towards high-level representation of acute disaster events, particularly in Global North countries. Non-peer-reviewed literature such as policy and planning documents, which may offer further insights into preparedness, were under-represented and could be a feature of next-generation research. Health systems need to be future proofed through effective policies, adequately trained workforces and redesigned infrastructure to meet the increasing burdens of climate change.

The majority of healthcare research on the impact of climate change examines the consequences for human health. Studies have focused on direct effects on health (for example, physical harm from heatwaves, hurricanes or extreme weather sequelae, such as floods and droughts) or indirect effects (for example, impaired food supply systems, increasing vectors for the transmission of diseases, population displacement and mental anguish, anxiety or depression about the threats of climate change)[1–3].

Less attention has been paid to the relationship between climate change and health systems, which have to deal with populations needing more or new care[4]. Crucial agencies such as the World Health Organization (WHO[5]) and the Organisation for Economic Co-operation and Development (OECD) have begun to recommend changes to increase the resilience of health systems to disasters and other challenges, such as new infectious diseases[6–8]. However, the effects of climate change are predicted not only to be more frequent disasters and emergent diseases, but to create longer periods of disruption as the duration of extreme temperatures and droughts extend[6,7,9]. Thus, adapting to climate change is not only about disaster preparedness but whole-system preparedness. It is critical to understand the disruptive consequences a changing climate will have on the systems of care; for example, whether or not current health systems are sufficiently well designed to cope with the additional pressures, volume and case types that human-induced change is producing, and the extent to which they are resilient, with enough reservoirs of capacity.

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Strategies and tactics to reduce the impact of healthcare on climate change: systematic review

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ABSTRACT

OBJECTIVE

To review the international literature and assess the ways healthcare systems are mitigating and can mitigate their carbon footprint, which is currently estimated to be more than 4.4% of global emissions.

DESIGN

Systematic review of empirical studies and grey literature to examine how healthcare services and institutions are limiting their greenhouse gas (GHG) emissions.

DATA SOURCES

Eight databases and authoritative reports were searched from inception dates to November 2023.

ELIGIBILITY CRITERIA FOR SELECTING STUDIES

Teams of investigators screened relevant publications against the inclusion criteria (eg, in English; discussed impact of healthcare systems on climate change), applying four quality appraisal tools, and results are reported in accordance with PRISMA (preferred reporting items for systematic reviews and meta-analyses).

RESULTS

Of 33 737 publications identified, 32 998 (97.8%) were excluded after title and abstract screening; 536 (72.5%) of the remaining publications were excluded after full text review. Two additional papers were identified, screened, and included through backward citation tracking. The 205 included studies applied empirical (n=88, 42.9%), review (n=60, 29.3%), narrative descriptive (n=53, 25.9%), and multiple (n=4, 2.0%) methods. More than half of the publications (51.5%) addressed the macro level of the healthcare system. Nine themes were identified using inductive analysis: changing clinical and surgical practices (n=107); enacting policies and governance (n=97); managing physical waste (n=83); changing organisational behaviour (n=76); actions of individuals and groups (eg, advocacy, community involvement; n=74); minimising travel and transportation (n=70); using tools for measuring GHG emissions (n=70); reducing emissions related to infrastructure (n=63); and decarbonising the supply chain (n=48).

CONCLUSIONS

Publications presented various strategies and tactics to reduce GHG emissions. These included changing clinical and surgical practices; using policies such as benchmarking and reporting at a facility level, and financial levers to reduce emissions from procurement; reducing physical waste; changing organisational culture through workforce training; supporting education on the benefits of decarbonisation; and involving patients in care planning. Numerous tools and frameworks were presented for measuring GHG emissions, but implementation and evaluation of the sustainability of initiatives were largely missing. At the macro level, decarbonisation approaches focused on energy grid emissions, infrastructure efficiency, and reducing supply chain emissions, including those from agriculture and supply of food products. Decarbonisation mechanisms at the micro and meso system levels ranged from reducing low value care, to choosing lower GHG options (eg, anaesthetic gases, rescue inhalers), to reducing travel. Based on these strategies and tactics, this study provides a framework to support the decarbonisation of healthcare systems.

SYSTEMATIC REVIEW REGISTRATION

PROSPERO: CRD42022383719.

WHAT IS ALREADY KNOWN ON THIS TOPIC

The carbon footprint of healthcare systems has been estimated at about 4.4% of global emissions, but comprehensive reviews investigating mitigation are lacking

One review took a global approach when examining the environmental impact of healthcare systems; however, this study was not peer reviewed and data were limited to one year

Another study discussed the sustainability of healthcare at a global level, however it was not conducted as a systematic review, and the methods used to evaluate and collate data were unclear

WHAT THIS STUDY ADDS

This review includes 18 years of studies, frameworks, and tools assessing the carbon footprint of healthcare systems, and the steps taken to measure and reduce these impacts

Overarching strategies and specific tactics, models, and tools were identified that could be used to decarbonise healthcare systems, aiming to reach net zero emissions by 2050

Introduction

The direct and indirect human health impacts of climate change have been well documented over the past two decades. The 2015 Paris Agreement and subsequent research have painstakingly established the association between planetary and human health.[1-4] However, until recently, less attention has been directed towards

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Disaster preparedness in Australian hospitals: A cross-sectional survey

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ARTICLE INFO

Keywords:
Hospital disaster preparedness
Disaster risk reduction
Disaster risk mitigation

ABSTRACT

Objective: This study examined the extent of disaster preparedness in Australian hospitals, seeking to identify opportunities for improvement. Insufficient preparation can lead to mortality/morbidity in post-disaster scenarios. Early identification of resolvable shortcomings in preparing for events is an important goal.
Materials and methods: A purpose-designed anonymous survey was distributed to all Local-Hospital-Networks, organizations responsible for managing public hospitals and their disaster preparedness, across Australia's six states and two territories. Participant recruitment targeted disaster-managers, emergency-preparedness-managers, and business-continuity-managers.
Results: Survey responses were received from 53/130 (40.8 %) of Australia's Local-Hospital-Networks with representation from six states and one territory. Most risk reduction measures were widely adopted. However, for 17/39 (43.6 %) measures, one-fifth of the respondents had either never heard of the measure or were not implementing it. Underutilized measures related to post-disaster-triage, emergency-evacuation, water-backup, secondary-electricity-feed, point-of-care-testing, alternative-decontamination-sites, and waste-management-systems. Local-Hospital-Networks' region-type, catchment-population and number-of-healthcare-facilities were associated with adoption of underutilized measures.
Conclusion: Although 22/39 (56.4 %) of carefully chosen measures were widely implemented, the state of Australia's disaster preparedness is variable. There remains room for improvement, particularly against an "all-hazards" standard. Limited implementation of disaster-triage, evacuation-measures, and procedural issues, suggests that Australian Local-Hospital-Networks, particularly those managing fewer facilities are not sufficiently prepared for catastrophes.

1. Introduction

Major disasters, both natural and human-made, often create challenges beyond those for which healthcare facilities have planned. Following the Fukushima earthquake, tsunami and nuclear power accident in Japan, almost half of the evacuated patients with stroke or renal failure died in vehicles, or on arrival at the hospital [21]. Despite Japan's longstanding nuclear disaster plans, bedridden patients were laid on bus seats and housed in a cold meeting room for extended periods, leading to cases of hypothermia, dehydration, and trauma due to falls from bus seats [21]. In another example, 72 patients died in three hospital evacuations necessitated by Hurricane Katrina, which ravaged south-eastern United States in 2005 [3]. These events underscore the risks that patients face if gaps are left in disaster planning, even in countries with advanced health systems. The likelihood of disasters compromising hospitals' functioning is expected to accelerate, due to increases in extreme weather events brought about by climate change [18]. A hospital experiencing a disaster could see a concurrent decline in its capacity to function alongside a rapid influx of injured patients, which can compromise care quality and increase death and complication risks.

1.1. Background & Rationale

In Australia, the importance of disaster preparedness is clear: Darwin hospital was bombed in World War II and then damaged again in a

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BMC Medicine

RESEARCH ARTICLE

Open Access

Progress with the Learning Health System 2.0: a rapid review of Learning Health Systems' responses to pandemics and climate change

Carolynn L. Smith[1,2*†], Georgia Fisher[1†], Putu Novi Arfirsta Dharmayani[1,2], Shalini Wijekulasuriya[1,2], Louise A. Ellis[1,2], Samantha Spanos[1], Genevieve Dammery[1,2], Yvonne Zurynski[1,2] and Jeffrey Braithwaite[1,2]

Abstract

Background Pandemics and climate change each challenge health systems through increasing numbers and new types of patients. To adapt to these challenges, leading health systems have embraced a Learning Health System (LHS) approach, aiming to increase the efficiency with which data is translated into actionable knowledge. This rapid review sought to determine how these health systems have used LHS frameworks to both address the challenges posed by the COVID-19 pandemic and climate change, and to prepare for future disturbances, and thus transition towards the LHS2.0.

Methods Three databases (Embase, Scopus, and PubMed) were searched for peer-reviewed literature published in English in the five years to March 2023. Publications were included if they described a real-world LHS's response to one or more of the following: the COVID-19 pandemic, future pandemics, current climate events, future climate change events. Data were extracted and thematically analyzed using the five dimensions of the Institute of Medicine/Zurynski-Braithwaite's LHS framework: *Science and Informatics*, *Patient-Clinician Partnerships, Continuous Learning Culture*, *Incentives*, and *Structure and Governance*.

Results The search yielded 182 unique publications, four of which reported on LHSs and climate change. Backward citation tracking yielded 13 additional pandemic-related publications. None of the climate change-related papers met the inclusion criteria. Thirty-two publications were included after full-text review. Most were case studies ($n=12$, 38%), narrative descriptions ($n=9$, 28%) or empirical studies ($n=9$, 28%). *Science and Informatics* ($n=31$, 97%), *Continuous Learning Culture* ($n=26$, 81%), *Structure and Governance* ($n=23$, 72%) were the most frequently discussed LHS dimensions. *Incentives* ($n=21$, 66%) and *Patient-Clinician Partnerships* ($n=18$, 56%) received less attention. Twenty-nine papers (91%) discussed benefits or opportunities created by pandemics to furthering the development of an LHS, compared to 22 papers (69%) that discussed challenges.

Conclusions An LHS 2.0 approach appears well-suited to responding to the rapidly changing and uncertain conditions of a pandemic, and, by extension, to preparing health systems for the effects of climate change. LHSs that embrace a continuous learning culture can inform patient care, public policy, and public messaging, and those

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BMC Health Services Research

RESEARCH

Open Access

Learning health systems on the front lines to strengthen care against future pandemics and climate change: a rapid review

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Abstract

Background An essential component of future-proofing health systems against future pandemics and climate change is strengthening the front lines of care: principally, emergency departments and primary care settings. To achieve this, these settings can adopt learning health system (LHS) principles, integrating data, evidence, and experience to continuously improve care delivery. This rapid review aimed to understand the ways in which LHS principles have been applied to primary care and emergency departments, the extent to which LHS approaches have been adopted in these key settings, and the factors that affect their adoption.

Methods Three academic databases (Embase, Scopus, and PubMed) were searched for full text articles reporting on LHSs in primary care and/or emergency departments published in the last five years. Articles were included if they had a primary focus on LHSs in primary care settings (general practice, allied health, multidisciplinary primary care, and community-based care) and/or emergency care settings. Data from included articles were catalogued and synthesised according to the modified Institute of Medicine's five-component framework for LHSs (science and informatics, patient-clinician partnerships, incentives, continuous learning culture, and structure and governance).

Results Thirty-seven articles were included, 32 of which reported LHSs in primary care settings and seven of which reported LHSs in emergency departments. Science and informatics was the most commonly reported LHS component, followed closely by continuous learning culture and structure and governance. Most articles ($n=30$) reported on LHSs that had been adopted, and many of the included articles ($n=17$) were descriptive reports of LHS approaches.

Conclusions Developing LHSs at the front lines of care is essential for future-proofing against current and new threats to health system sustainability, such as pandemic- and climate change-induced events. Limited research has examined the application of LHS concepts to emergency care settings. Implementation science should be utilised to better understand the factors influencing adoption of LHS approaches on the front lines of care, so that all five LHS components can be progressed in these settings.

Keywords Learning health systems, Learning care systems, Primary care, Emergency department, Implementation science, Review

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SPECIAL ISSUE ARTICLE

WILEY

Bolstering health systems to cope with the impacts of climate change events: A review of the evidence on workforce planning, upskilling, and capacity building

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Abstract

Background: As global CO_2 emissions continue to rise and the 'era of global boiling' takes hold, the health workforce must cope with the challenge of providing care to increasing numbers of patients affected by climate change-related events (e.g., hurricanes, wildfires, floods). In this review, we describe the impacts of these events on the health workforce, and strategies responding to these challenges.

Methods: This rapid systematic review was guided by the Preferred Reporting Items for Systematic reviews and Meta-Analyses and a registered protocol (PROSPERO CRD42023433610). Eight databases were searched in May 2022 and again in June 2023. Empirical studies discussing climate change and workforce policy, planning, preparedness, and capacity were included. Inductive thematic analysis of extracted data was conducted.

Appendix 1. List of team members of the Observatory on the Future of Healthcare

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Appendix 2. The National Roundtable on the Impact of Climate Change on Human Health – bridging research and action for a sustainable future

Attendees at the National Roundtable on the Impact of Climate Change on Human Health, Australian Institute of Health Innovation, March 2024.

The national 'Roundtable on the Impact of Climate Change on Human Health – bridging research and action for a sustainable future' was held on 19 March 2024, convened by Professor Jeffrey Braithwaite, Founding Director of the Australian Institute of Health Innovation (AIHI) at Macquarie University.

The Roundtable was attended by 51 people from around the country representing health, government, agency, academic and consumer groups, including a peak consumer body and an independent consumer.

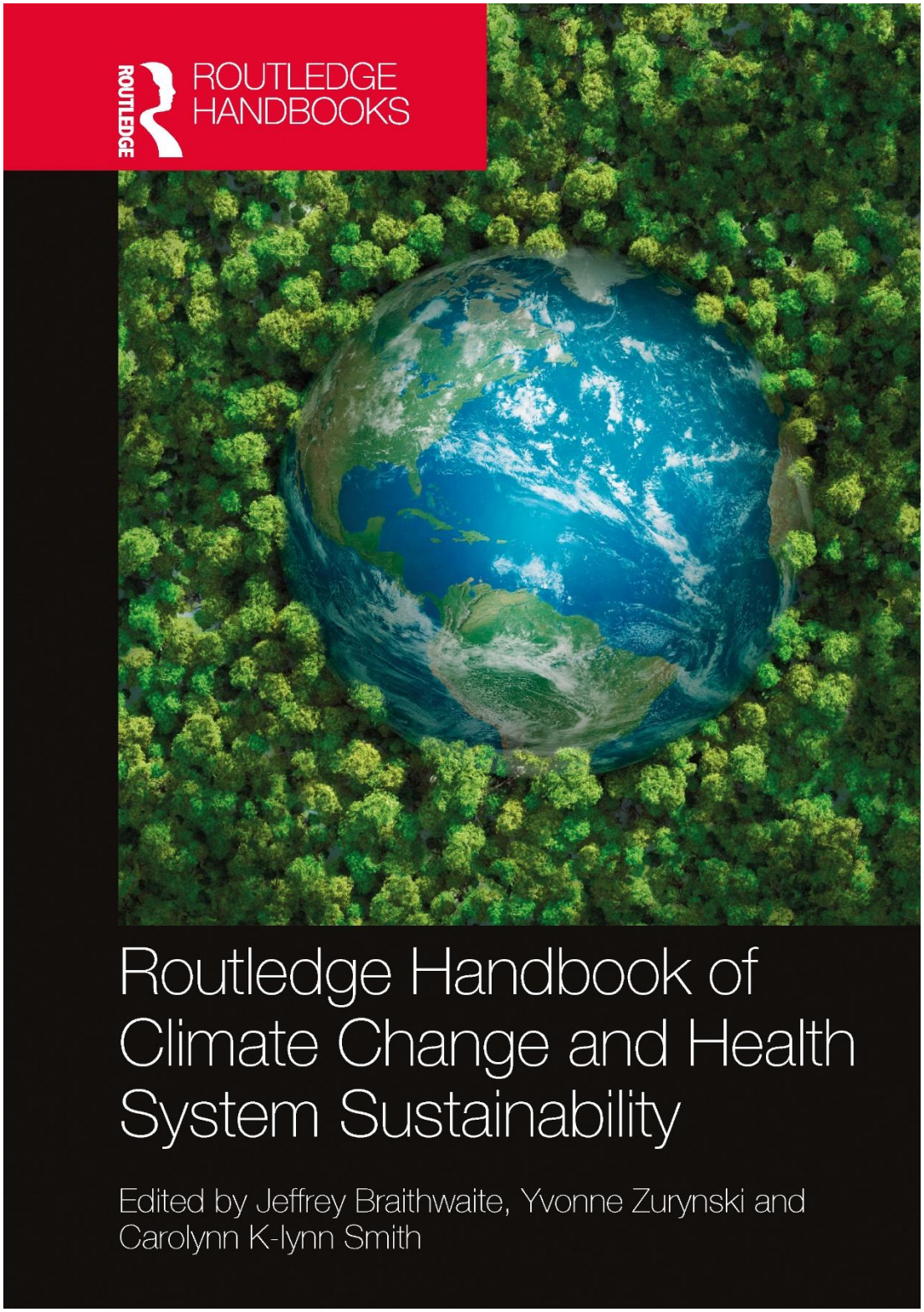
The Roundtable galvanised thought leaders to design the next generation of research on the impact of climate change on human health and health system sustainability for Australia. Discussions were framed by a series of lightning talks by key spokespeople:

- Professor Jeffrey Braithwaite, Founding Director, Australian Institute of Health Innovation
- Professor Odette Best, Professor of Nursing (Indigenous Research and Community Engagement), and Pro-Vice Chancellor, University of Southern Queensland
- Dr Anthony Brown, Executive Director, Health Consumers NSW
- Associate Professor Martin Hensher, Menzies Institute for Medical Research, University of Tasmania
- Ms Julie Farrington, Principal Policy Officer, NSW Health
- Ms Bettina McMahon, Chief Executive Officer, Healthdirect Australia
- Professor Enrico Coiera, Director, Centre for Health Informatics, Australian Institute of Health Innovation

- Professor Ian Hickie, Professor of Psychiatry and the Co-Director of Health and Policy, Brain and Mind Centre, University of Sydney
- Professor Yvonne Zurynski, Professor of Health System Sustainability, Macquarie University, Australian Institute of Health Innovation

The outcomes of the roundtable were shared with all participants, health departments and agencies in Australia and have informed future research directions.

Appendix 3. Routledge Handbook of Climate Change and Health System Sustainability



The *Routledge Handbook of Climate Change and Health System Sustainability* is a major work of 480 pages, with three editors and 75 authors. It takes the reader on a journey to understand the interconnectedness of human health, climate change, and healthcare.

The book begins by exploring how climate change is affecting human health through the increasing frequency of natural disasters, such as wildfires, droughts and heatwaves, and the emergence of new infectious diseases, such as COVID-19, all of which drive up demand for health services that are already heavily burdened by increasing rates of chronic diseases and ageing populations. Chapters then turn to the contribution of the healthcare system itself to climate change—explaining how current clinical practices, e.g., low value care, create an unsustainable carbon footprint and threaten the system's viability. Across the volume, descriptions of practical solutions and case studies illustrate the feasibility of taking action in the real world of the healthcare ecosystem. It is a clarion call for stronger systems which can cope with advancing climate-induced problems: vector-borne diseases e.g., Lyme disease, Dengue fever, West Nile virus; and weather-accelerated problems with consequences e.g., floods, forest fires, heatwaves, droughts.

The book brings together a mix of forward-thinking environmental and health researchers, policymakers, leaders, managers, clinicians, patients, and health industry leaders to create sustainable healthcare systems. It is a book of reckoning, but of pivotal value: of interest to many, including researchers and policymakers of climate and health systems.

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