UNIVERSITY OF TORONTO
Collaborative Centre for Climate, Health & Sustainable Care

TRANSFORM HF

Principles & Priorities for Sustainable Digital Health in Cardiology

WORKSHOP REPORT

April 23-24, 2024

Executive Summary

THE CHALLENGE

Climate change poses a fundamental threat to social stability and human health. The main response to the climate change challenge is a global commitment to reduce emissions and increase environmental sustainability across all sectors.

Health systems have a central role to play in this global response; cardiology, as a major component of health systems, must act.

Cardiology is undergoing a digital transformation marked by advances in imaging, remote monitoring, virtual care, and precision medicine that has promise both in terms of improved care delivery and increased environmental sustainability. However, if we fail to fully explore and understand the full impacts of this digital transformation, any 'promise' may instead lead to sustainability perils.

OUR PURPOSE

TRANSFORM HF and the Collaborative Centre for Climate, Health & Sustainable Care (CCCHSC) brought together international thought leaders in sustainable health systems, digital health innovations, and cardiology for a Workshop on the Principles and Perils for Sustainable Digital Health. The workshop, held April 23 and 24 2024, provided a platform to discuss principles and priorities to inform policies and investments in a sustainable digital transformation of cardiology that are relevant to the digital transformation of health systems more broadly. The workshop involved a participatory and open process that was first focused on the identification of the promises and perils inherent in the digital transformation of cardiology and then moved to the identification of key enablers and impediments for ensuring that transformation is environmentally sustainable. Form there, the workshop moved to defining strategies for addressing roadblocks to sustainable digital transformation, guiding principles, and concrete next steps for future efforts.

IDENTIFYING PRINCIPLES & PRIORITIES OF SUSTAINABLE DIGITAL TRANSFORMATION

The **promises** of digital transformation were defined as benefits that digital transformation offered to individuals, health systems, and society. These included reduction in travel and waste, empowerment through information, actionable data, evidenced-based decision making, optimization of care delivery, and facilitation of diagnosis and management.

Enablers were defined as factors or components that facilitate the successful adoption of sustainable digital transformation. These included equitable access, interoperability, interdisciplinary teams, and a more holistic approach to defining health benefits that includes environmental costs.

The **perils** of digital transformation were defined as the risks, drawback, and negative consequences of digital innovation. These included regulatory and environmental challenges, complexity of environmental impact assessment, lack of human resources, excess enthusiasm for unproven AI solutions, ethical dilemmas in data use, and unintended consequences on more holistic ways of understanding.

Impediments to sustainable digital transformation were defined as barriers, obstacles, or challenges that could hinder sustainable digital transformation. These included consolidation of power in a small number of big tech companies, lack of a clear conceptual framework for action on digital sustainability, issues of cybersecurity, competing interests in a complex stakeholder context, environmental impacts of large AI models, the large volume of data, rapid technological advancement, and the need to emphasize the indispensable role of human judgement.

OVERCOMING IMPEDIMENTS & LEVERAGING ENABLERS

Participants identified consolidation of power as a key potential threat. It was agreed that we must find better ways to navigate relationships between the public sector and 'big tech' and include a broader set of stakeholders in discussions around ground-up solutions for procurement, ownership, and cybersecurity. This effort could be supported by scenario-planning exercises that incorporate experience with previous technological innovation.

A key enabler for success is a commitment to equitable access that ensures an equity lens is used; innovation does not increase the digital divide; and collected data is useful, easily accessible, and actionable for healthcare providers. These efforts will increase demand for specialized skills and knowledge within various disciplines to effectively address challenges and opportunities associated with sustainable digital health – its innovation, implementation, and governance. Participants recognized the need to build a diverse workforce capable of driving sustainable digital health initiatives forward.

GUIDING PRINCIPLES

We must inventory what is known to be important in terms of sustainability in order to determine standardized methods to measure/quantify the environmental impact of research/digital health tools and systems. Such an inventory would also support advocacy efforts for the investment in research on sustainable healthcare practices to generate evidence-based recommendations and solutions, as well as for the inclusion of meaningful sustainability considerations in funding applications – whether that be carbon calculators, environmental impact assessments, or another standardized method.

Ensuring healthcare research, practices, and associated resource allocation align with principles of environmental sustainability and social responsibility should be a primary goal moving forward. This will likely involve defining digital health, adapting the definition of sustainability to the context of digital innovation, consolidating resources for researchers on the best practices for sustainable digital health, integrating the notion of sufficiency into research, and engaging the public to understand priorities and perceptions around trade-offs.

CONCRETE NEXT STEPS

1. Establish a Community of Practice
2. Synthesize knowledge by pursuing publication(s)
3. Generate new knowledge by exploring funding opportunities

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Our Challenge

There is growing international recognition of the fundamental threat that climate change poses to social stability and human health, as well as the need for widespread response. During this time of rapid change, digital transformation is often seen as a key pathway to economy-wide emission reductions. However, if we fail to fully explore and understand the impacts of a digital economic transformation, we run the risk of increasing rather than decreasing emissions and other ecological harms. Thus, a deep contradiction is posed by digital transformation in a climate constrained world.

Healthcare comprises more than 10% of the global economy. The sector is highly resource intensive and polluting, responsible for almost 5% of global greenhouse gas (GHG) emissions. Digital transformation is increasingly promoted as a critical strategy in efforts to reduce healthcare GHG emissions. Cardiology has embarked on its own significant digital transformation, marked by advances in imaging, remote monitoring, virtual care, and precision medicine. This transformation has catalyzed debate about access, equity, ethics, outcomes, and now sustainability. New digital technologies may reduce travel and waste and improve appropriateness of care, and therefore play a vital role in lowering the carbon footprint of healthcare. At the same time, digital transformation could add services of limited benefit, create new forms of waste, and increase cardiology's energy-driven carbon footprint through the expansion of digital networks, data storage and computationally intense analytics. As a result, cardiology presents an important case through which to explore the environmental promises and perils of digital health transformation.

Cardiologists alone cannot pursue this exploration. It is imperative that cardiologists leading this digital transformation collaborate with social scientists, data scientists, environmental scientists, ethicists and other experts who understand and can assess environmental impacts to develop best practices for a low carbon transition for cardiology.

TRANSFORM HF and the Collaborative Centre for Climate, Health & Sustainable Care (CCCHSC) came together with international thought leaders in sustainable health systems, digital health innovations, and cardiology for a *Workshop on the Principles and Perils for Sustainable Digital Health*. Participants' expertise spanned social sciences and humanities, environmental studies and sciences, and health and computational sciences, including clinical care, lived experience, policy, and system management. For a list of attendees, please see Appendix 1.

TRANSFORM HF, an institutional strategic initiative formed in partnership between the University of Toronto and the Ted Rogers Centre for Heart Research, is committed to advancing equitable access to high-quality heart failure care through digital innovation.

The **Collaborative Centre for Climate, Health & Sustainable Care** (CCCHSC) is a multi-faculty unit at the University of Toronto. The Collaborative Centre's purpose is to catalyze climate & sustainability action for health & health systems through research, education, and practice & policy change.

The Workshop

PURPOSE & GOALS

This two-day workshop was intended to provide a platform to discuss principles and priorities that could inform policies and investments in the sustainable digital transformation of cardiology, with implications for health systems more broadly.

In the short-term, the workshop aimed to unite a group of multi-disciplinary and multi-sectoral thought leaders, identify shared priorities around the advancement of sustainable digital health in cardiology, and produce a supporting call to action. In the long-term, it is hoped that the collaboration forged by the workshop will support the development of standards for the exploration, testing, and evaluation of digital health tools, pursue research ventures to design and test sustainable solutions and mobilize a community of interested stakeholders seeking a sustainable future.

PREPARING FOR THE WORKSHOP

As a first step, TRANSFORM HF and the Collaborative Centre conducted literature reviews and environmental scans at the intersection of sustainable digital health and the digital transformation of cardiology. The team then identified and engaged experts in social sciences, humanities, environmental studies/sciences, digital health, health systems and policy, and cardiology.

To help focus workshop structure, a survey on sustainable digital health was distributed to participants and key thought leaders were engaged in one-on-one interviews. These surveys and interviews helped elucidate key themes, research questions of interest and avenues for deeper exploration during the workshop. For a summary of survey results, see Appendix 2.

TRANSFORM HF and the Collaborative Centre provided a list of attendee bios and recommended readings to all participants ahead of the workshop to help level set among the different perspectives in attendance. For a list of the distributed readings, please see Appendix 3.

WORKSHOP STRUCTURE & FORMAT

The workshop occurred over two days in Toronto, Canada. Each activity was intentionally designed to iterate upon the previous activity, integrating learnings and driving towards consensus building around shared priorities and areas of concern at individual, small group, and plenary levels. Notetakers were present to record small and large group discussions.

The first evening of the workshop began with welcomes from Drs. Heather Ross and Fiona Miller, respective leads of TRANSFORM HF and the Collaborative Centre. This was followed by the opportunity for attendees to introduce themselves and provide some initial perspectives, moderated by TRANSFORM HF Director of Strategy and Translation, Anne Simard.

Dr Ross offered reflections on the potential of digital innovation to address deep challenges of access and equity for the patients in her care, and to improve opportunities for self-management alongside improved health outcomes. She further reflected on the climate benefits of digital health interventions that provide timely care at enormous distance, without requiring unnecessary, costly, and carbon-expensive travel. Dr Ross closed by reflecting that, despite the potential benefits, digital innovations might ultimately come at too great a climate cost, in particular because of the explosion of health data and AI analytics.

Fiona Miller offered two sustainability concepts for group consideration: efficiency and sufficiency. Efficiency, she argued, is a common and often-useful response to the demands of sustainability, seeking to do more with less. The challenge, she noted is that while efficiency often yields reduced impact from each unit of activity, it also often yields greater activity, leading to the “rebound effect” of greater – not reduced – environmental harm. The concept of “sufficiency” is therefore also essential, suggesting – as it does – the need to limit activity by some assessment of what is “enough”. This, she further argued, is a major challenge in the context of health data and digital innovation, given the increase in both volumes of data, and intensity of analytic capacity.

Dr. Geoffrey Anderson then provided a short presentation to set the stage for the workshop. That presentation began by identifying two important themes, the commitment to sustainable healthcare as part of the global response to climate change and the digital transformation of healthcare as a part of ongoing efforts to improve health by making care more accessible, effective and efficient. He went on to suggest that focusing on sustainable digital transformation of cardiology provides a real opportunity to more clearly articulate and apply principles and strategies for addressing these two important themes. It was noted that there has been some important work done on sustainable healthcare and sustainable digital transformation by the thought leaders attending the workshop that was shared with attendees as readings prior to the workshop. It was noted that the goal of the workshop was to bring together people thinking about and involved in sustainable healthcare together with people thinking about and involved in the digital transformation of cardiology, to listen to new ideas and see issues from different perspectives, to find common ground, and to develop a message that can engage others. The slides from that presentation can be found in Appendix 4).

The next morning, the full day workshop was kicked off with a presentation of emergent themes and principles from the pre-workshop surveys and interviews.

A keynote presentation was then delivered by Dr. Gabby Samuel on the promises and perils of digital transformation (Appendix 5).

Participants then moved into working sessions. First, they individually reflected on their vision for the future of sustainable digital health, including a ‘promise’ and ‘enabler,’ as well as a ‘peril’ and ‘impediment’ inherent in the development/adoption of digital innovations. In small groups (five groups of four to six participants from different disciplinary backgrounds), participants shared and expanded upon these visions, recording themes on post-it notes. A plenary dialogue around this small group activity followed. All post-its from this activity were collected, grouped in thematic clusters, and posted on a wall. Group review clarified themes and allowed for dissemination of the smaller group discussions.

A prioritization exercise followed during which participants voted on threats and opportunities of greatest concern or potential. Group consensus around priorities began to emerge with potential for a call to action.

A post-it note wall allowed participants to share their identified promises (green), enablers (pink), impediments (yellow), and perils (orange) of sustainable digital health, as well as prioritize the most crucial themes using stickers. This collaborative exercise allowed the group to collectively identify and focus on key areas for future development and action in digital health.

The afternoon activities focused on elaborating on these identified priorities in detail. Highest rated promises/enablers and perils/impediments (with the most votes) were assigned back to each small group. Small groups then discussed:

1) how to address or overcome perils/impediments
2) how to advance promises/enablers.

Groups summarized their discussion and solutions, presenting during a plenary discussion.

Building on the plenary discussion, the team led a final consolidation of consensus and determined next steps.

For a full agenda of the day, see Appendix 6.

The Journey

OUR SHARED VISION

Participants were called to individually and collectively reflect on their vision for the future of sustainable healthcare and digital health.

> The **Lancet Commission on Sustainable Healthcare**'s definition of sustainable healthcare systems was used to level set, and is as follows:
>
> *Sustainable healthcare systems provide universal access to appropriate care that optimizes health and wellbeing for today's patients and communities, as well as for future generations by delivery of care that is **needed**, **wanted**, **clinically effective**, **affordable**, **equitable**, **responsible in its use of resources**, and **functioning within planetary boundaries**.*

Several common themes were present:

- Human-Centered Care

  Our shared vision for the future sees high-quality, patient-centered care supported by human connection, empathy, and patient-care team relationships. Value-based care models prioritize patient outcomes, satisfaction, and well-being over the volume of services provided.

  The impact of human touch on patient care and wellbeing is profound; an overreliance on technology should not come at the expense of this connection. Healthcare policy and practice must ensure a balance between technology and humanity; human-centered care must be at the forefront, with support from digital innovations – not the other way around.

- Sustainable Healthcare

  Just as environmental factors impact human health, our healthcare systems impact environmental health. As a result, it is important that healthcare resources are aligned with actual needs to ensure effective delivery, and that sustainable practices are embedded within healthcare systems to mitigate environmental risks.

  Collaborative efforts and holistic approaches are necessary to advance sustainable healthcare practices that benefit both individuals and the planet.

  Consideration must be given to the balance of short-term healthcare needs with long-term environmental sustainability goals, recognizing the complexities of navigating these trade-offs.

- Interdisciplinary Collaboration

  Participants envision thinkers and researchers from the social sciences, health sciences, and natural sciences and engineering and People with Lived Experience (PWLE) all working in an interdisciplinary manner to create sustainable digital health solutions – improving outcomes for patients and the planet.

  Students and trainees should have access to interdisciplinary courses and translational research programs from the very beginning of their training to facilitate knowledge exchange and equip them with skills and knowledge to address complex healthcare challenges, develop holistic care approaches, and excel in complex and rapidly changing environments.

- Equity and Access

  Disparities in healthcare access and outcomes must be understood and actively addressed.

  Digital health technologies should be used to improve access for equity seeking populations; these solutions should be designed for equity to ensure they meet the specific needs of diverse populations and do not widen the digital divide.

  Healthcare delivery and technology development should be informed by diverse, representative data and social determinants of health; alternative care sources beyond emergency rooms are pursued to ensure inclusive healthcare delivery.

PROMISES, PERILS, ENABLERS, AND IMPEDIMENTS

Many promises/enablers and perils/impediments emerged from discussions around the group's shared vision of sustainable healthcare. Below we capture the ideas that were put forward, but were not necessarily endorsed by all participants.

While recognizing the transformative potential of digital health, participants remained cognizant of the ethical, regulatory, and environmental considerations for responsible innovation. The discussions underscored the imperative of navigating the digital health landscape with prudence and foresight, ensuring that technological advancements serve as catalysts for equitable, patient-centric care delivery.

Promises: Potential benefits and positive outcomes that digital health technologies offer to individuals, healthcare systems, and society	**Reduction of Travel Emissions and Waste** Participants noted an obvious strength of digital health tools was the potential to reduce travel emissions and waste associated with in-person appointments, under some circumstances.
	Empowerment Through Information: Participants saw promise in the potential of digital health technologies to empower patients by providing them with comprehensive insights into their own health. This empowerment was envisioned to lead to greater patient engagement and adherence, thereby fostering improved health outcomes.
	Useful, Usable, and Actionable Data: Thanks to AI and digital tools, previously unwieldy data sets can now be leveraged to perform predictive analytics, diagnoses, and management to ultimately improve health outcomes.
	Evidence-Based Decision Making: Integral to the promise of digital health is its capacity to facilitate evidence-based decision-making, ensuring that interventions are grounded in empirical evidence. At the same time, digital tools must be held to appropriate standards of evidence, i.e., appropriately researched, sound methodology, published in peer reviewed journals.
	Optimization of Healthcare Delivery: Digital health innovations were viewed as important enablers for optimized healthcare delivery. Through the deployment of advanced decision support systems and machine

	learning algorithms, participants envisioned a paradigm shift towards improved allocation of healthcare resources to maximize patient benefit.
	Facilitation of Diagnoses and Management: The role of artificial intelligence (AI) in augmenting diagnostic accuracy and healthcare management was noted. Participants highlighted AI's capacity to process large datasets, thereby facilitating timely diagnoses and personalized treatment regimens.
Perils: Potential risks, drawbacks, and negative consequences associated with the adoption and implementation of digital health technologies.	**Regulatory and Environmental Challenges:** The integration of AI into healthcare necessitates robust regulatory frameworks to mitigate risks and ensure patient safety. Additionally, participants deliberated on the environmental footprint of digital health technologies, highlighting the at times competing interests of validated and evidence-based technologies, the constant push for innovation and more data, and the need to address climate change and environmental impacts.
	Complexity of Environmental Impact Assessment: Measuring the broader environmental impact of digital health technologies emerged as a formidable challenge. Participants grappled with the intricacies of quantifying environmental footprints *including and beyond carbon emissions*, recognizing the complexity inherent in assessing the holistic environmental ramifications of healthcare practices.
	Lack of Human Resources: There is an unfilled need for highly qualified personnel who understand the language, terminology, and implications of environmental sustainability across disciplines. A holistic view of the potential impacts of digital health development and implementation and fully informed decision-making will not be possible without the appropriate capacity building.
	Excess Enthusiasm for AI & AI-Driven Solutions: Participants expressed apprehension regarding the risk of excess enthusiasm for AI's role in decision making, or 'fetishization' of AI and data. Participants cautioned against the blind adoption of/undue trust in AI, emphasizing the irreplaceable role of human expertise in contextualizing and interpreting clinical data.

	Ethical Dilemmas in Data Utilization: The responsible use of health data was a common thread across discussions. Participants articulated concerns regarding data privacy, security breaches, and the potential for algorithmic biases, underscoring the imperative of safeguarding ethical principles amidst technological advancement.
	Unintended Consequences Participants recognized that growing quantities of data may responsibilize people in ways that disrupt more holistic ways of understanding and mobilizing health and wellbeing, thus having unintended negative consequences. As well, the goal of improved diagnosis is improved outcomes. Diagnostic accuracy is not guaranteed to generate such improvement. It may involve over-diagnosis and lead to over-treament and associated harms
Enablers: Factors or components that facilitates the successful adoption, implementation, and utilization of digital health technologies.	**Equitable Access** When designed for equity, participants believe that digital tools hold great potential to address some disparities in care, empower some self-management, and improve some outcomes in some populations.
	Interoperability and Systems Approach Creating systems that work together seamlessly, though a challenge, provides great opportunity to leverage the full potential of digital health technologies.
	Interdisciplinary Teams Participants recognize that having a variety of perspectives and skills present on a team helps better address complex healthcare challenges and develop effective and holistic care approaches.
	Best Practices Adherence to best practices for data management and engagement provide opportunity to enhance transparency and mitigate risks associated with data misuse.
	Holistic Health

	Participants deliberated on the balance between maximizing health benefits and minimizing environmental impact. They discussed the perception that digital health innovation is always beneficial and contributes to positive health outcomes, while recognizing there may be financial and environmental costs. The need to have integrative, holistic approaches to evaluating and using digital health were underscored.
Impediments: Barrier, obstacle, or challenge that hinders the effective deployment and utilization of digital health technologies.	**Consolidation of Power** Participants viewed the consolidation of power among big tech companies as a major threat, with implications for equity, access, and control over data, resources, and technology.
	Lack of Conceptual Framework A lack of a conceptual framework for innovation upstream of implementation poses a challenge for accelerating investments in digital innovation in health in a responsible manner.
	Cybersecurity Moving towards connected, cloud-based platforms and increasing reliance on digital tools creates heightened vulnerability to system failures and cyber-attacks especially if advancements in healthcare infrastructure and innovations continue to lag behind other sectors and technologies. Meanwhile, investing in cybersecurity must be recognized as a financial and environmental cost of digitalization.
	Competing / conflicting interests Participants noted that there is inherent conflict among different stakeholders, with each group defending its own priorities and needs. Questions were raised over decision-making processes and who has the right to act and implement changes in such a multi-faceted environment.
	Environmental Impact: Participants underscored the ecological footprint associated with the maintenance and operation of large AI models. There was a collective call to assess the environmental costs

	vis-à-vis the incremental value provided by AI systems in healthcare, highlighting the imperative of environmental sustainability.
	Volume of Data: The sheer magnitude of data involved in AI applications emerged as a significant impediment. Participants underscored the challenge of discerning crucial data for decision-making amidst the deluge of information, highlighting the potential for inefficiencies and escalating costs without commensurate benefits. As well, some participants questioned whether the availability of – and potential for even more – data was serving as a highly inappropriate driver of activity. Rather than being driven by supply, health research and service activity should be driven by need. They countered that understanding the need didn't always require more and more data, and that sometimes the demand for data was a significant issue to be overcome.
	Rapid Technological Advancements: The exponential pace of AI technological investigation poses a formidable challenge, especially in regard to evaluating usefulness of tools. Participants deliberated on the imperative of ensuring that human stakeholders can effectively adapt to and engage with evolving technologies to remain integral to the decision-making process, and highlighted the importance of a "responsible research and innovation" paradigm, premised on a clear-headed assessment of need, potential and social accountability, rather than hope, opportunity and supply.
	Human in the Loop: The dialogue emphasized the indispensable role of human judgment in conjunction with AI technologies to avert errors that AI might not autonomously recognize. Participants advocated for maintaining human expertise as a central component of the decision-making process, but acknowledge the near-impossibility of maintaining the "human in the loop" given the volume and speed of data-driven capacity.

ADDRESSING ROADBLOCKS & SOLUTIONING

Through group discussions and a voting exercise, five themes were prioritized and associated areas for further inquiry were identified:

1. <u>The peril of consolidation of power</u>

   There has been an observable shift/consolidation of power to 'big tech' companies, closely related to the impediment of competing/conflicting interests. Participants viewed this as a key threat to a sustainable future, requiring effective communication and collaboration to address.

   - Consider how best to navigate relationships between the tech and public sector.
   - Explore ground-up solutions via procurement, ownership, etc.
   - Identify who should be at the table for further discussions, including those who have not traditionally had a seat, people with lived experience, and environmental thought leaders.
   - Identify stakeholder perspectives, agendas, and incentives.
   - Balance interests to negotiate a collective definition of value.
   - Conduct scenario planning exercises to learn from past lessons around technological advancement/check against past claims of innovative technologies (i.e., AI) and to anticipate and understand the trajectories and uncertainties inherent to different possible futures.

2. <u>The promise of equitable access</u>

   Digital health innovations such as remote diagnostic and monitoring technologies hold promise for underserved/isolated communities. However, unequal access and barriers to technology can contribute to further disparities. To bridge this 'digital divide,' innovations must be designed with a health equity lens that considers the end user and a suite of geographic, socioeconomic, cultural, and regulatory factors.

   - Use digital health tools as a *complement* to care, considering for whom and in what circumstances digital tools are favourable to face-to-face appointments.
   - Pursue and expand triage systems enabling remote monitoring and self-management in remote or rural settings.
   - Build platforms for inclusive stakeholder engagement from diverse perspectives.
   - Reflect patient and clinician feedback, preferences, and values as tangible metrics.
   - Better describe the relationship between equity and sustainability.
   - Consider who is responsible (high/middle/low-income countries) for advancing sustainable digital health, especially in the context of past and future pandemics and pandemic preparedness (i.e., single use plastic and PPE)

3. The promise of useful, usable, and actional data
   Ensuring that we collect the data we need, and that collected data is useful, easily accessible, and actionable for healthcare providers is crucial for leveraging the full potential of digital health technologies. Further, equity and bias in data acquisition, analysis, and application must be fully understood to ensure ethical and sustainable solutions.
   - Be cognizant that data begets data, and this comes with associated costs.
   - Focus on 'looking beyond the lamppost' to see more broadly, and ensure that data is unbiased and representative and that solutions are equitable and accessible.
   - Improve data accessibility and transparency for patients to foster empowerment, communication, and patient-centered care; approaches must streamline data access processes, enhance data literacy, and strengthen data governance frameworks.
   - Conduct forecasting exercises to solidify where we want to end up, identify areas of deep uncertainty, and develop a roadmap of how to get there.[1]

4. The peril of cybersecurity
   Participants noted that safeguarding sensitive healthcare data is of paramount importance, and that keeping up with the pace of technological change and innovation is, and will continue to be, an ongoing challenge.
   - Identify the gaps in existing rules, regulations, and governing mechanisms
   - Determine risk tolerance levels/values and accepted trade-offs between security and suability to identify appropriate measures (investments in technology, crisis protocols).
   - Identify environmental costs.
   - Enhance the resilience of digital health systems – how can systems be interconnected yet secure from system failures or cyberattacks?
   - Equip staff with cybersecurity training.

5. The impediment of limited human resources
   There is a demand for specialized skills and knowledge within various disciplines to effectively address challenges and opportunities associated with sustainable digital health – it's innovation, implementation, and governance. Participants recognized the need to build a diverse workforce capable of driving sustainable digital health initiatives forward.
   - Pursue the designation of a new class of professionals versed in sustainable healthcare / digital health.
   - Pursue bottom-up, early training of the next and current generation of health professionals focused on interdisciplinary collaboration.

[1] Consult the Environmental Governance Lab's "We Did It!" exercise on a future history of net zero in Canada.

Further, two guiding principles were identified as lenses to apply to all actions moving forward:

1. Environmental impact
   Sustainability was identified as a key principle that must underpin all technological and policy developments to ensure long-term viability and ethical responsibility.
   - Inventory what we know to be important in terms of sustainability to determine standardized methods to measure/quantify environmental impact of research/digital health tools and systems.
   - Advocate for the investment in research on sustainable healthcare practices to generate evidence-based recommendations and solutions.
   - Advocate for the inclusion of meaningful sustainability considerations in funding applications, whether that be carbon calculators, environmental impact assessments, or another standardized method. Be cognizant of greenwashing.
2. Responsible research
   Ensuring healthcare research, healthcare practices and associated resource allocation align with principles of environmental sustainability and social responsibility requires further exploration and continual re-evaluation.
   - Define digital health; adapt the definition of sustainability to address digital technologies development and implementation.
   - Consider resources/waste, intersectionality, sustainability, etc.
   - Consolidate resources for researchers on the best practices for sustainable digital health to enable responsible research.
   - Integrate the idea of sufficiency into research: What is enough? What am I doing? What does it mean? What is the potential significance and impact?
   - Foster public engagement to understand priorities and perceptions around trade-offs.

Co-Host Call to Action

Through this interdisciplinary workshop, we reframed the context to assess the sustainability of digital health innovations from different perspectives, such as environmental, patient, social sciences, economic, and clinical.

Together, we challenged the presumptions that innovation is always beneficial, that more data is always needed, that increased accuracy is always advantageous, and that digital care is inherently good. We identified a significant peril in the current supply-driven approach to innovation; where we should be asking what data is needed to answer the questions that need answering, we are instead driving analytical capacity to manage the seemingly unlimited quantities of data that it is possible to generate. It is important to note that having data is not the same as having evidence; seeking data is not the same as seeking to be evidence-based.

We recognized that with the development and implementation of digital health comes the potential for waste, excessive consumption, and irresponsible research and care. It is **imperative** that all new technologies are grounded in empirical evidence, and that the true cost and value of improved accuracy facilitated by AI be understood – what is the allowable cost for incremental improvement with uncertain increased benefit? There are significant gaps in the evaluation of new tools and innovations, and the measurement of their outcomes.

It is a frightening reality that innovations are occurring at an alarming rate with little line of sight to regulatory review, great potential socioeconomic and environmental costs, and negligible (or even negative), yield and benefit.

Our reflections on the paradox of digital health will help inform future actions around **responsible** digital innovation, and the measurement of impact and outcomes in a new way that is holistic of **all** factors.

Action Items & Next Steps

The following actions were identified as preferred next steps:

1. Establish a Community of Practice

   Collaborate with global CoP and networks such as SHADE.

   As we start to formulate strategies out of the Workshop, identify key players who were missing from this workshop and bring them together with attendees to:

   - Define digital health and sustainable digital health
   - Develop standardized methods/practical guidelines for integrating sustainability into research, tech development, and health implementation
   - Draft a call to action around sustainable digital health
   - Advocate for environmental sustainability and responsible research to be accepted by funding agencies as key principles

2. Synthesize knowledge by pursuing publication(s)

   Draw on the definition of sustainable digital health drafted by the Community of Practice and workshop outcomes to write a paper(s) on the principles and priorities for sustainable digital health:

   - Embed cardiology case studies to target the Journal of the American College of Cardiology
   - Apply backcasting and forecasting techniques to explore the 'future history' of sustainable digital health

3. Generate new knowledge by exploring funding opportunities

   Elaborate on the research questions that emerged from the survey responses as well as the deliberations of the workshop (see Appendix X for research questions).

   Pursue funding opportunities on a local and international scale, notably:

   - In Canada:
     - New Frontiers in Research Fund
     - CIHR Project Grant
     - CIHR Catalyst Grant – Community-Based Research in Climate Change Priority Areas
     - NSERC Discovery Grant
   - International:
     - WHO
     - Wellcome Trust
     - World Bank
     - PARIS-DE

4. Stimulate capacity and interest in Sustainable Digital Health, ideally with a cardiology lens

   Use existing funding mechanisms of the collaborators – potentially amplified by external parties or University of Toronto. Such mechanisms might include:

   - Joint focussed research call between the Collaborative Centre and TRANSFORM HF such as a Collaboration Starter Grant or Seed Grant (i.e., co-funded by the partners and jointly promoted to members of each network).
   - Co-sponsored and co-supervised fellows who bridge the mission of each partner and build capacity for sustainable digital health research and education.

   Consider opportunities for joint educational or promotional events that raise awareness and advance the dialogue on sustainability in health care.

5. Conduct research

   Pursue a 'green' RCT to develop and test methods and guidelines in a clinical setting.

   Specifically, we hope to explore the measurement, evaluation, and validation of digital health through a climate lens. This includes quantifying the trade-off between innovation and accuracy with climate impacts.

Appendices

ATTENDEE INFORMATION

SURVEY RESULTS

PREPARATORY READING LIST

GEOFFREY ANDERSON'S PRESENTATION

GABRIELLE SAMUEL'S PRESENTATION

WORKSHOP AGENDA

ATTENDEE BIOS

HEALTH SYSTEM & SUSTAINABILITY THOUGHT LEADERS

Dr. Nicoda Foster

Dr. Foster is the Managing Director of the Sustainable Development Goals Institutional Strategic Initiative at the University of Toronto. She is strongly committed to addressing the underlying causes of inequity that affect the most vulnerable in our society.

Dr. Foster has held several progressive administrative roles with organizations such as Sinai Health System where she was instrumental in the development of the Geriatrics program's evaluation and research program and the Registered Nurses Association of Ontario where she supported the uptake of their world renowned best practice guidelines into nursing practice.

Ms. Lovisa Gustafsson

Ms. Gustafsson is the Vice president of the Controlling Health Care Costs program and leads the Climate and Health initiative at the Commonwealth Fund. In these roles she oversees the programmatic work, including grant making, in the areas of prescription drug policy, health care prices, and decarbonization of the health system.

Prior to joining the Fund, Ms. Gustafsson served as senior vice president for the Marwood Group, a health care advisory organization, where she managed various outsourced private equity due diligence and strategy consulting engagements. Before her role at the Marwood Group, she worked as a manager in corporate strategy and business development at McKesson, a senior consulting associate in quality and operations support for Kaiser Permanente, a senior policy analyst at the Commonwealth of Massachusetts Office of Medicaid, and a manager at Avalere Health LLC. Ms. Gustafsson earned an M.B.A. in health care management from the Wharton School at the University of Pennsylvania and a B.A. in sociology from Harvard University.

Mr. Simon Hagens

Simon Hagens is the Vice President of Performance at Canada Health Infoway. He leads performance analytics to inform the delivery and optimization of digital health for the benefit of Canadians and our health system.

Prior to Infoway, Simon has been a manager in a primary care and community health organization, where he led the implementation of an electronic medical record system. As a market researcher in the pharmaceutical industry, Simon applied a variety of qualitative and quantitative research approaches to provide intelligence andrecommendations for marketing major products. Simon holds a B.Sc from the University of Guelph and an MBA from McGill University.

Mr. Matt Hulse

Mr. Hulse is a professional electrical, computer, and software systems engineer with diverse experience in embedded devices and digital communication technologies. He possess extensive knowledge of photovoltaic systems, networking and telecommunication protocols, and have unique experience in radio and broadcast engineering. His specialization is in energy and communication infrastructure in developing communities and emerging markets. His work experience spans many countries and disciplines through accomplishments in industry, public sector, and non-profit institutions.

Dr. Matt Ratto

Dr. Ratto is Professor in the Faculty of Information at the University of Toronto and the Bell University Labs Chair in Human Computer Interaction. His research focuses on how theories and perspectives from technoscience research can usefully extend and contextualize design and engineering practice, particularly related to emerging digital health technologies.

He studies and practices ‘critical making’, work that combines humanities insights and engineering practices and has published extensively on this concept. Based on new research, Dr. Ratto recently published a CHI conference workshop paper on new approaches to the design of AI-powered therapeutic conversational agents (CHI 2021.)

Dr. Gabrielle (Gabby) Samuel

Dr. Samuel is a lecturer in the Department of Global Health & Social Medicine at King's College London and co-Director of SHADE - a research group and network at the intersection of Sustainability, Health, AI, Digital technologies, and the Environment. Her main research interests relate to the social/ethical issues associated with digital health, big data, and AI.

Gabby is particularly interested in the environmental impacts of these technologies and her research programme explores ethical and governance issues related to this. She has argued that the moral gaze of technologies should include not only their use, but also where they have come from and where they are disposed. She draws on concepts of sustainability, justice, power, equity, responsibility and neo-liberalism to do this. She is particularly interested in decision-making and how values-trade-offs are balanced, and how this relates to moral obligation, responsibility, justice and critical justice scholarship. Gabby's research is funded by a range of grants, including a Wellcome Fellowship, which is exploring the environmental sustainability of data-driven health research.

Dr. Hardeep Singh

Dr. Singh is a Professor of Medicine at the Center for Innovations in Quality, Effectiveness and Safety based at the Michael E. DeBakey Veterans Affairs Medical Center and Baylor College of Medicine, Houston. He leads a portfolio of multidisciplinary quality and safety research focused on measurement and reduction of medical errors, improving the use of health information technology and health system transformation.

He represents the US Department of Veterans Affairs (VA) on the National Academy of Medicine's Climate Collaborative and has proposed several system-level approaches and strategies related to decarbonization of health care delivery. He co-chaired the Technical Expert Panel that developed "Reducing Healthcare Carbon Emissions: A Primer on Measures and Actions for Healthcare Organizations to Mitigate Climate Change." He is serving on the Executive Committee of the newly launched Lancet Planetary Health Commission on Sustainable Healthcare where he also co-leads the Environmental Performance & Quality Measures Working Group.

Dr. Jodi Sherman

Dr. Sherman is an Associate Professor of Anesthesiology of the Yale School of Medicine, Associate Professor of Epidemiology in Environmental Health Sciences, and founding director of the Yale Program on Healthcare Environmental Sustainability in the Yale Center on Climate Change and Health. She also serves as the Medical Director of Sustainability for Yale-New Haven Health System.

Dr. Sherman is an internationally recognized researcher in the emerging field of sustainability in clinical care. Her research interest is in life cycle assessment of environmental emissions, human health impacts, and economic impacts of drugs, devices, clinical care pathways, and health systems. Her work seeks to establish sustainability metrics, paired with health outcomes and costs, to help guide clinical decision-making, professional behaviors, and organizational management toward more ecologically sustainable practices to improve the quality, safety, and value of clinical care and to protect public health.

Dr. Sherman is a member of the Lancet Countdown on Health and Climate Change and was contributing analyst for the UK National Health Service Net Zero Initiative, and serves on the National Academy of Medicine Action Collaborative for Decarbonization of the U.S. Health Sector. She is Co-Director of the Lancet Planetary Health Commission on Sustainable Healthcare.

Mr. Erwin Van Hout

Mr. Van Hout is the Chief of Technology Transformation at The Hospital for Sick Children, where he leads the technology workstream for Project Horizon, a campus redevelopment plan to build an inspired hospital of the future and transform how care is delivered. He is passionate about leveraging emerging technologies, innovation, and foresight to enable, empower, and enhance the staff, physicians, researchers, patients, and families at SickKids.

With over 20 years of business and technology infrastructure experience, he is a technology strategist who plans, develops, and implements end-to-end IT solutions across various industry verticals, including healthcare, telecommunications, pharmaceuticals, and professional services.

CARDIOLOGY & DIGITAL HEALTH INNOVATORS

Dr. Darshan Brahmbhatt

Dr. Brahmbhatt is a board certified Cardiologist and Internal Medicine Physician. His academic interests include innovations in heart failure care and remote monitoring. He is clinically focussed on heart failure, complex implantable devices, and cardiac transplantation. He has recently taken up a post as Heart Failure Attending at Mount Sinai Hospital in Toronto.

Dr. Jennifer Gibson

Dr. Jennifer Gibson is Sun Life Financial Chair in Bioethics and Director, Joint Centre for Bioethics (JCB) and Associate Professor, Division of Clinical Public Health and Institute of Health Policy, Management, & Evaluation, Dalla Lana School of Public Health, University of Toronto. Jennifer leads the AMS-Fitzgerald Fellowship in AI and Human-Centred Leadership at the Joint Centre for Bioethics, is a member of the WHO Expert Group on Ethics and Governance of Artificial Intelligence for Health and recently completed a 3-year term as Vice-Chair of the Ontario Health Data Council.

Dr. Gibson's program of research and teaching focuses on health system and policy ethics from an interdisciplinary perspective. She is interested in the role, interaction and influence of human values in the design, development and deployment of technology in health systems locally and globally and in decision-making about technology use within a broader societal context.

Dr. Muhammad Mamdani

Dr. Mamdani is Vice President of Data Science and Advanced Analytics at Unity Health Toronto and Director of the University of Toronto Temerty Faculty of Medicine Centre for Artificial Intelligence Education and Research in Medicine (T-CAIREM). Dr. Mamdani's team bridges advanced analytics including machine learning with clinical and management decision making to improve patient outcomes and hospital efficiency. He is also adjunct Senior Scientist at the Institute for Clinical Evaluative Sciences (ICES) and a Faculty Affiliate of the Vector Institute, which is a leading institution for artificial intelligence research in Canada.

Dr. Mamdani's research interests include pharmacoepidemiology, pharmacoeconomics, drug policy, and the application of advanced analytics approaches to clinical problems and health policy decision-making. He has previously been named among Canada's Top 40 under 40 and has published over 500 studies in peer-reviewed healthcare journals.

Dr. Chris McIntosh

Dr. McIntosh is a Scientist at the Techna Institute, the Peter Munk Cardiac Centre, and the Joint Department of Medical Imaging, at the University Health Network, and an Assistant Professor in the Dept. of Medical Biophysics at the University of Toronto.

In 2012 he joined the Department of Radiation Physics as a Research Associate working in the labs of Drs. Tom Purdie and David Jaffray; his and Tom Purdie's work has since been commercialized and is now deployed in hospitals around the world, using AI to deliver reproducible, high quality cancer care. In 2019 he started his own lab focusing on the theory and clinical application of AI in medicine for improving patient care including transfer learning, meta learning, computer vision, and explainable AI. Applications include deep learning for automated diagnosis, segmentation, quality assurance, and treatment planning.

Dr. Yas Moayedi

Dr. Moayedi is an advanced heart failure and transplant cardiologist at Toronto General Hospital, University Health Network. She has subspecialty training in Cardiology and a fellowship in Advanced Heart Failure Therapies. Dr. Moayedi studied Digital Health and Precision Medicine at Stanford University and pursued a Master's in Translational Research at the University of Toronto.

Yas is dedicated to reducing health inequities through technology and mobile health, with a firm belief in making excellent patient care accessible to all.

Dr. Abhinav Sharma

Dr. Sharma is Assistant Professor in the Department of Medicine, Divisions of Cardiology and Experimental Medicine at McGill University.

His research is in the field of digital health, with a focus on how to optimize health behaviours in order to improve outcomes in patients with cardiovascular disease and diabetes. His research group focuses on two major themes: on cardiovascular outcomes and therapy optimization in patients with diabetes and heart failure; and on the use of digital health to streamline follow-up and therapy selection in patients with heart failure. The aim is to develop new tools to leverage novel biomarkers, digital data, and electronic health records to conduct clinical studies, optimize patient data collection, and enhance knowledge translation.

Dr. Jay Shaw

Dr. Shaw is the Tier 2 Canada Research Chair in Responsible Health Innovation and an Assistant Professor in the Department of Physical Therapy at University of Toronto. He serves as Research Director of Artificial Intelligence (AI), Ethics & Health at the University of Toronto Joint Centre for Bioethics, an appointment in the Department of Physical Therapy, and is adjunct Scientist at the Women's College Hospital Institute for Health System Solutions and Virtual Care. He practiced as a physical therapist in community-based care prior to completing his PhD in 2012.

Jay's program of research addresses the implementation and ethical/social implications of innovations in health care, with a special focus on digital health technologies, applications of AI in health care, and other equity-focused health innovations.

Dr. Lynne Warner Stevenson

Dr. Stevenson is the Lisa Jacobson Professor of Cardiovascular Medicine and Director of Cardiomyopathy at Vanderbilt University Medical Center. She has contributed to 30+ national guidelines for heart failure, transplantation, and cardiomyopathies. With support from NHLBI, she has played leadership roles in trials developing strategies of care for heart failure, including the INTERMACS registry for ventricular assist devices, with over 20,000 patients.

Dr. Stevenson's research has focused on the physiology and profiles of advanced heart failure and the personalization of therapies for patient goals to extend length and quality of life. Her current practice focuses on the early recognition and clinical profiling of genetic cardiomyopathies. In 2021, she received the Lifetime Achievement Award from the Heart Failure Society of America.

Dr. Nicole Weckman

Dr. Weckman is the Paul Cadario Chair in Global Engineering at the University of Toronto. Her research focuses on developing the next generation of point-of-care technologies for diagnosing diseases and monitoring outbreaks of drug-resistant infections. Her research group develops sensitive and quantitative biological and biochemical sensors at the interface of cell-free synthetic biology and microscale and nanoscale sensing systems by focusing on engineering design for clinical and commercial translation.

She is particularly interested in developing low-cost and sustainable diagnostics that can help to improve health equity. Beyond her academic work, Dr. Weckman is co-founder of the start-up 52 North Health, where she is working in the medical diagnostic space to develop low-cost digitally linked technologies that help improve health outcomes and health equity for people receiving chemotherapy.

Dr. Camellia Zakaria

Dr. Zakaria is an Assistant Professor in the Biostatistics Division and Institute of Health Policy, Management, and Evaluation (IHPME) at the Dalla Lana School of Public Health (DLSPH), University of Toronto.

The orientation of her research is as affirmative as it is critical in fulfilling the long-term vision "toward sustainable mobile health – one which provides anecdotal evidence to support personalized and precision medicine while driving population health values." Grounded in Systems research, her investigations lie in the intersecting subfields of Mobile and Ubiquitous Computing, Applied Machine Learning, and Human-Computer Interaction.

PEOPLE WITH LIVED EXPERIENCE

Mr. Sheldon Daley

Sheldon Daley is a patient partner with a congenital genetic disorder that manifested as Heart Failure and Neutropenia. He had a heart transplant approximately four years ago. Daley is currently in his 4th year at the University of Toronto studying Ecology and Evolutionary Biology, Human Biology, and Medical Anthropology.

Sheldon is interested in understanding care gaps in the healthcare system and social dynamics in healthcare, and intends to pursue a masters in Epidemiology.

Ms. Dina Theodoropoulos

Constantina Dina Theodoropoulos is a caregiver for over 40 years to her mother who has been living with heart disease and heart failure most of her life. She studied mathematics and sociology at the University of Toronto then pursued a career in interior design and build.

Dina is proud to have chaired, co-chaired, and championed in the healthcare space. She has always had an interest in being part of community, volunteering her time, and engaging in initiatives that would enhance fellow humans and their health.

TRAINEES

Dr. Renzo Calderon Anyosa

Dr. Renzo Calderon is a post-doctoral fellow at the Institute for Pandemics at the University of Toronto. He completed his Ph.D. in Epidemiology at McGill University and achieved an MD and MSc in Biomedical Informatics in Global Health from Cayetano Heredia University in Lima, Peru. During his doctoral journey, Dr. Calderon centered his research on the application of quasi-experimental methodologies for policy assessment. His current research interests are concentrated on the evaluation of public policies, both in the midst of and in the aftermath of the COVID-19 pandemic. This involves delving into areas such as mental health, societal and gender disparities in healthcare, chronic diseases, and the integration of communication technologies within the realm of public health and merging diverse data streams and constructing tools.

Mr. Joseph Donia

Joseph Donia, MSc, is a PhD Candidate at the Institute of Health Policy, Management & Evaluation, University of Toronto, where his research addresses the ethics, policy, and governance of data-intensive health innovation. His work has been published in leading interdisciplinary venues including Big Data and Society, Science and Engineering Ethics, and the AAAI/ACM Conference on AI, Ethics, and Society (AIES).

Ms. Lola Oyefeso

Lola Oyefeso, a Human Biology student specializing in Global Health at the University of Toronto, is dedicated to addressing healthcare disparities. Her research focuses on community-focused integrated care and digital health, utilizing AI and cutting-edge technology. She has lead various initiatives promoting diversity and inclusion in healthcare. Her passion for transforming healthcare centers around the potent intersection of AI technology and innovation, revolutionizing the industry. As a student researcher at the University of Toronto Joint Centre for Bioethics, Lola contributes to cutting-edge models of community-focused integrated care, digital health technologies, and AI applications.

HOSTS & PLANNING TEAM

Dr. Fiona Miller

Dr. Miller is a Full Professor in the Institute of Health Policy, Management and Evaluation at University of Toronto. She holds the Chair in Health Management Strategies and is a Connaught Scholar.

Miller leads efforts to improve the sustainability of health systems through research, education, and practice change through her roles as Director of UofT's Collaborative Centre for Climate, Health, and Sustainable Care; Director of the national CASCADES initiative for climate action in healthcare; and member of the global Sustainability, Health, AI, Digital technologies, and the Environment (SHADE) research hub. She also brings a political economy perspective to the policy analysis of technological innovation and sustainability transitions.

Dr. Geoff Anderson

Dr. Anderson is a Full Professor in the Institute of Health Policy, Management and Evaluation, University of Toronto. He has been involved in health services research for over 20 years, with a growing focus on examining the climate impacts of digital transformations in healthcare; he is an Affiliated Faculty of UofT's Collaborative Centre for Climate, Health & Sustainable Care.

Anderson has strong expertise in integrated health and community care at multiple levels, and brings his knowledge of international best practice and opportunities for health system transformation.

Dr. Heather Ross

Dr. Ross is Head, Division of Cardiology; Loretta A. Rogers Chair in Heart Function at University Health Network; Site Lead for the Ted Rogers Centre for Heart Research; Professor of Medicine at the University of Toronto; and co-lead of TRANSFORM HF.

Ross was named to the Order of Canada in 2021 for her contributions to cardiac care, including innovative solutions to predict, detect, and follow cardiac events using digital technologies. She recently led a research study evaluating the carbon impacts of Medly, an application she co-invented to remotely monitor and manage heart failure.

Dr. Michael Elfassy

Dr. Elfassy is a Resident Physician in the Cardiology Residency Program at the University of Toronto. He completed his MD and Internal Medicine Residency at the University of Toronto as well as an MSc in Global Health at McMaster University.

Dr. Elfassy's scholarly interests include health systems solutions, quality and innovation within cardiovascular care. He was recently primary author on an article exploring carbon cost reductions associated with remote medication titration for advanced heart failure published in JACC in April 2024. He hopes to integrate artificial Intelligence into his work and collaborate with like-minded clinicians and scientists.

Ms. Anne Simard

Anne Simard is the Director of Research for the Ted Rogers Centre for Heart Research (TRCHR) at University Health Network, and Director of Strategy and Translation for TRANSFORM HF.

She leads research, training, and clinical initiatives dedicated to digital health innovation, health equity, and engagement of people with lived experience of heart failure. Anne also leads several patient experience, patient engagement, and knowledge mobilization initiatives at the TRCHR.

Mr. Alex Titeu

Alexandru is a Research Administration Officer at the Institute for Health Policy, Management and Evaluation (IHPME). In his previous roles he has supported healthcare organizations in the collection and analysis of improvement data, and worked on research projects with the Canadian Patient Safety Institute (CPSI) and the North American Observatory on Health Systems and Policies (NAO).

Ms. Augusta Lipscombe

Augusta is Program Manager at TRANSFORM HF. She completed a Bachelors of Science at the University of Guelph and a Master of Marine Management at Dalhousie University, following which she began a career in science communications. For the past seven years, Augusta has worked with non-profit organizations and educational institutions to translate knowledge into accessible content and build community engagement.

VISION FOR THE FUTURE OF DIGITAL HEALTH...

- Eco-friendly digital infrastructure that minimizes environmental impact.
- Digital technologies need to replace technologies with larger individual footprints… build the digital technologies themselves, including models, with minimal footprint.
- Aligned with the goals of climate/environmental movements around the world; based on renewable resources/energy systems; data ownership is determined by communities whose data is collected specifically for Black and Indigenous groups; challenges agism in the adoption of digital tech.
- Civil society, including young people, women, older persons, persons with disabilities and marginalized and hard-to-reach communities, must be involved at all levels of planning, execution and monitoring of digital health. International actors and the private sector should ensure their investments are coordinated and aligned with national priorities. Without this, there is a risk of fragmentation/duplication/waste. There is need for coordination among stakeholders and international donors under leadership of the government.
- Sustainable digital health will be end-user centric, well resourced, purpose-driven, and sustainable with tangible and meaningful returns on investment. Ideally, it will lead to more efficient care and better patient outcomes.
- Sustainable digital health requires a blended approach that addresses the physiological as well as environmental determinants of health. In this latter category we should include biological conditions, such as air and water quality, climate, and access to bio-diversity, as well as the spatial impacts of economic and social conditions, given that these are typically linked.
- Advancements in digital health are aligned with actual health system needs rather than technological advances that add marginal to no value. Defining 'value' holistically, to consider not only value to individual patients, providers, or areas of specialization, but to equitable and sustainable health care systems more broadly.
- Combination of remote care with triggers and alerts/videohealth/and in person visits to address common cardiology problems: Patients receive the right intensity of attention to note new issues and to manage known issues. The varied staff involved would be assigned according to skill level for cognitive processing, reassurance, or recognition for upward triage, according to the common events.
- Complex and future-minded, taking advantage of the flexibility allowed by the use of digital technology. Time saving and accessible, taking advantage of the reach and connectivity digital technology allows. Effective in both care and reducing negative environmental effects.
- Considerations around the energy consumption of data centers that power cloud-based health applications. Use of more efficient IT/equipment, use of IT/equipment to monitor and control energy consumption/waste related to buildings and support services, and use of IT/equipment to influence care delivery and clinical decision-making.
- The development of digital hardware is practiced with sustainable supply chains, respects and reinforces social and economic wellbeing of the local regions from which materials are acquired; digital technologies pay strong attention to the environmental wellbeing and sustainability of local regions and broader regions in the world.

THE PROMISE OF DIGITAL HEALTH IN CARDIOLOGY

CREATING POSITIVE IMPACTS ON THE ENVIRONMENT, PATIENTS & WORKFORCE

- Advanced tech to support evidence based care that 1) reduces costs, emissions, and waste, 2) increases access and reliability, and 3) optimizes costs in terms of finance and personnel while still providing high quality care.
- All stakeholders perceive enough personal and shared benefits to endorse and invest in its survival and growth.
- Streamlining data quantity capture, transmission and storage; clean energy, circular economy for electronic devices/capital equipment; equity of broadband and tech access.

EMBED SUSTAINABILITY IN DIGITAL HEALTH DESIGN, IMPLEMENTATION & FUNDING

- Provide alternatives to conventional healthcare that take into consideration the environment, including distribution of labour, centralization of power and digital infrastructures, hardware, and supply chains.
- Practices of design, distribution, use, and governance of tech are interwoven with sustainability as key concern.
- Tech solutions aren't based on quick wins, but long-term solutions; it is sustainable (carbon-neutral, doesn't contribute to resource extraction/mining) and reusable/recyclable/doesn’t become obsolete. Tools should be easily adoptable, and make work easier.
- More investment from domestic and international sources, better coordinated/aligned investments. Costed digital health strategies and investment road maps. Mechanisms for meaningful multi-stakeholder engagement and improved digital connectivity.

BALANCING INTERESTS, OR ‘EDGES’ OF THE SWORD

- Double-edged sword: environmental impacts from the creation of models and devices BUT may be offset by the reduced travel and hospitalizations.
- Could provide new platforms of delivering, translating/transferring, and improving health care with enough accuracy, equity, and efficiency that all users derive enough fulfillment to ensure digital health thrives. One challenge will be to incentivize collaboration rather than domination among platforms.
- Savings in transportation, duplication, medical documentation, and billing costs may fuel continued investment.

MULTIPLE COMPONENTS TO SUSTAINABLE DIGITAL HEALTH

- Sustainability refers to 1) financial; 2) digital data; 3) patient safety. It includes financial/resource, human engagement, environmental considerations, and geopolitical considerations.
- Relationship between environment and health, emphasizing an 'externalist' approach to care that focuses on both 'internal' impacts of genetics and lifestyle and 'external' effects related to aspects of our environments.

ENVIRONMENTALLY-CONSCIOUS MEDICINE

- The environmentally conscious practice of medicine, implementing digital health when appropriate.
- Become more environmentally conscious in the healthcare field by developing methods to reduce carbon footprint but not jeopardize quality patient care. Enhance patient care.
- Address critical gaps that are growing in the health care professions. No system will be sustainable if the rising frustration/fulfillment ratio continues to drive early retirement of experienced doctors and nurses and dampen recruitment of new medical professionals. Digital health is too often equated with a reduction in work force, when the currently thinning work force instead needs to grow to make digital health succeed.

THE PERILS OF DIGITAL HEALTH IN CARDIOLOGY

CREATES/REINFORCES INEQUITIES AND GAPS IN ACCESS

- If poorly executed, it will result in greater inefficiency and wasted resources as well as public harm.
- That digital technologies reinforce existing structures of regional and global inequity.
- Equity of access. Creating models that impact patient quality of life instead of simply adding to electronics landfills.
- Access to internet is a challenge for many rural and remote communities across Canada that must be addressed
- Big data/too much data without benefit to patients and with detriment to energy/material requirements to support; social justice issues around rare earth metal mining (e.g. women/childrens rights violations in DRC); technology creep, prolonging death at great expense and suffering.
- Not everyone will have access/know to use it and may have to rely on another person to help them and miss out on the extra benefits of monitoring their vitals. The cost of owning a smart device or the cost of the internet could play a factor on many patients missing out on a great opportunity to help in their health. Accessibility to all is important.

CONSOLIDATION OF POWER & CONTROL; ENVIRONMENTAL IMPACTS

- Centralization of power by large corporate actors with resources to control access to infrastructures, data sets, hardware, etc. Concerns around the outsourcing and conditions of related labour. Academic and medical incentive schemes that do not prioritize sustainability, but the advancement of innovation tech and knowledge.
- While multiple systems need to be tested and to coexist and communicate, one of many challenges will be to incentivize collaboration rather than domination among platforms.
- Concerned about centralization of data by private actors and the externalization of control over health that can attend privatization and economic control by non-health care organizations.
- Emissions from technology use itself including AI
- Reimbursement models, data storage and safety

MEASURING IMPACT & VALUE OF DIGITAL HEALTH

- How do we measure that the digital transformation of health indeed minimizes the impact on our environment
- There is a lack of robust evidence on the clinical benefit and cost implications of digital health tools. When adding a climate lens, it's really important to have clear clinical effectiveness information that both clinicians and patients understand and trust to make clear that clinical effectiveness isn't being sacrificed for other metrics.
- Digital is not a panacea. Specific to sustainability and climate, the role for digital health tech must account for both mitigating its carbon-costs, as well as for facilitating resilient, high-quality, adaptable health systems. Much to be learned on the wisdom of the last era of digital transformation and eHealth around interoperability, incentives, coordination, use-centered design, and linking tech use to outcomes.
- 1st focus should be to provide the best health care possible, with reduced env consequences being a 2nd outcome.

IMPORTANCE OF ROLE & NURTURING HEALTH CARE PROFESSIONALS

- Nothing will be sustainable if early retirement of experienced clinicians and dampen recruitment of new ones continues. Digital health is too often equated with a reduction in work force, when really it requires an increase in trained personnel to succeed. Define and begin training a new mid-level medical professional.
- Vision of what 'good' looks like for healthcare needs to be kept central, with digital being an important part of delivering that in the modern complex connected world - but without losing human qualities and interactions.

BEST PRACTICES FOR SUSTAINABLE HEALTH CARE

MEASUREMENT & EVALUATION

- Focus on measuring and evaluating the impact on both patient care and sustainability goals.
- Foster a culture of sustainability within cardiology . Offer training and education on sustainable practices.
- Socio-technical impact assessments, attending to the diverse set of considerations required to advance sustainable health care, while grounding use of those more technocratic tools in inclusive and accountable governance arrangements that include diverse perspectives, including those from the global south.
- Build a case, learn from data, implement practices to reduce emissions, sustain.

PATIENT ENGAGEMENT & LOCAL LEADERSHIP

- Best practices are primarily about local design and ownership. However, there is an obvious tension between these best practices and the "scale-up" focus on industry and health care.
- Best practices include patient engagement with their chronic health problems, including authorization to adjust care.
- Co-design of tools that gain traction in typical care - such as excellent video platforms for consultation (many such); integrated medical records that are designed to support work flow and patient and HCP experience (not EPIC!)

DESIGN FOR LOW-CARBON, LOW-IMPACT

- Groups examining biodiversity using digital imaging technologies tend to ensure tech is light weight and reusable.
- How to create synthetic data, how to rapid enable digital projects to emerge.

CARE PATHWAYS & SYSTEMS WITH MIX OF COMPETENCIES & PROFESSIONS

- Urgent visits and hospitalizations can be reduced by patient access to some 24/7 human triage with ready access to home-monitored data, but caveat for next point:
- Care will be more efficient when a new designation of support personnel are trained to help patients decrease their reliance on physician staff and health care facilities to address behavioral and social challenges.
- Any integrated system is more efficient when it is responsible for ALL of health care costs, including staff, hospitalizations, home care, and end of life care. (e.g., Canadian system, Kaiser in California)

DIGITAL HEALTH PATHWAYS THAT ARE MEASURED & OPTIMIZED

- Digital/remote appointments… improves care as a whole, increases accessibility by patients who may have trouble getting to their appointments, eliminates travel time and expenses for the patient. Environmental benefits are also significant, as it eliminates emissions related to transport and energy use.
- In person appts along with virtual/remote monitoring… incredibly benefiting patient care.

REFER TO OTHER GUIDELINES & BEST PRACTICES

1. Principles for Donor Alignment for Digital Health – published by the Digital Investment Principles. Best practices to collaborate/prioritise national plans/quantify costs/track & measure/strengthen donor skills
2. Canada’s Sustainable Future – National Action Plan
3. Natalie Jerimejenko's Environmental Health Clinic project at NYU; is an artist-scientist … more speculative vein, but the concepts are a creative and intriguing starting place.

RESEARCH QUESTIONS TO EXPLORE

Align with the goals of climate/environment movements and researchers around the world to develop research questions and policy directions:

- What are the relationships between digital health inequities and climate-related inequities? how can digital health and global sustainability agenda be brought together?

Create a Framework, Guidelines and Measurement Tools:

- Need for a measurement tool and guidelines for environmentally responsible digital health,
- Identify and document more examples of digital health in response of the health system to climate shocks (both where digital assisted health system resilience, and where there was system failure
- Research these case studies of digital health responding to climate shocks.

Explore, quantify and act on environmental considerations of digital health:

- What are the relative environmental impacts of traditional vs digitally led care pathways.
- We need precise reporting of the type of events and triage decisions currently made in large practices, by the baseline diagnosis. Then we can better allocate the training and numbers of staff to receive and respond.
- How might we characterize the supply chains for digital health technologies? What sustainability issues are represented by those supply chains?
- Reusability/lifespan of technologies (e.g., reuse technologies people already have).

Within Cardiology:

- What is the impact of digital health on waste and emissions in cardiology
- What are the best practices to improve sustainability in cardiology in terms of policy and practice
- What are some things that cardiologists can do differently in their daily practice
- Compare whatever digital health plan is tested to the same plan to which is added a friendly voice on the phone who can be in contact with a large # of health care providers.
- Test different ratios of remote monitoring/ videohealth visits/office visits.
- How can telehealth and remote monitoring technologies be optimized to improve access to cardiology care?

Focus on patient outcomes

- What improves outcomes and experience of care; what increases convenience for patients and their families;
- What are key success factors for sustainable scale up?
- How to move beyond the physiological body in considering sustainability and health?
- What are digital tools and platforms for patient education on heart-healthy lifestyles?
- Bias and equity implications of interventions and underlying data.

Within AI and Data Science:

- How can we create synthetic data to enable more advances to be uncovered. How to enable cost recovery and how will this be reimbursed? What are the metrics to show that we can improve outcomes?
- What is essential vs excessive data/storage/tech?
- How can AI and ML algorithms be developed to enhance diagnostic accuracy in cardiology?

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Perspective

i-CLIMATE: a "clinical climate informatics" action framework to reduce environmental pollution from healthcare

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ABSTRACT

Addressing environmental pollution and climate change is one of the biggest sociotechnical challenges of our time. While information technology has led to improvements in healthcare, it has also contributed to increased energy usage, destructive natural resource extraction, piles of e-waste, and increased greenhouse gases. We introduce a framework "Information technology-enabled Clinical cLimate InforMAtics acTions for the Environment" (i-CLIMATE) to illustrate how clinical informatics can help reduce healthcare's environmental pollution and climate-related impacts using 5 actionable components: (1) create a circular economy for health IT, (2) reduce energy consumption through smarter use of health IT, (3) support more environmentally friendly decision-making by clinicians and health administrators, (4) mobilize healthcare workforce environmental stewardship through informatics, and (5) Inform policies and regulations for change. We define Clinical Climate Informatics as a field that applies data, information, and knowledge management principles to operationalize components of the i-CLIMATE Framework.

Key words: climate change, electronic health records, clinical climate informatics, medical informatics, i-CLIMATE

INTRODUCTION

Addressing environmental pollution, climate change, and ultimately the sustainability of our planet as we know it represents one of the biggest sociotechnical challenges of our time.[1] Tremendous improvements in technology and specifically information technology over the past 60 years have led to global progress in nearly all sectors and industries of our modern economy. In the healthcare sector, improvements in healthcare delivery have been enabled by electronic health records (EHRs) and the development of large, centralized medical centers. However, many of these same improvements have also contributed to increased energy usage,[2] destructive natural resource extraction,[3] piles of electronic waste (e-waste),[4] unsustainable increases in greenhouse gas emissions (GHGs),[5] and global warming. US healthcare contributes 8.5% of national greenhouse gases that, along with similar fractions of harmful air pollutants, cause indirect harm similar in magnitude to medical errors.[6] Reducing healthcare pollution is, therefore, a social, moral, professional, and economic imperative.[7]

Health information technology (IT) tools and applications, specifically the EHR, are now an integral part of healthcare delivery and can be used to support decarbonization efforts (ie, reducing the release of greenhouse gases into the atmosphere), reductions in electronic and plastic waste, and increased environmental sustainability (ie, meeting the needs of the present while maintaining ecological balance and not compromising the needs of the future).[8] But, EHR-related hardware and software also introduce challenges such as increased natural resource extraction, energy consumption, e-waste, and manufactured obsolescence.[9] Returning to paper-based medical record-keeping systems is not an option, from either a healthcare quality, patient safety, or environmental sustainability perspective. Health IT must be used intelligently and to its fullest capacity to ensure safe, effective, high-quality patient care, while also helping address healthcare-related environmental pollution and climate change.

GUIDING PRINCIPLES FOR A CLINICAL INFORMATICS-CENTRIC APPROACH TO REDUCE ENVIRONMENTAL POLLUTION FROM HEALTHCARE

We propose 3 principles that should guide an informatics-centric approach to how information technology can and should be used to reduce healthcare's carbon emissions and electronic waste and promote sustainability. These principles are based on expert opinions of the authors gained from previous health IT[10] and environmental sustainability work,[11] a review of the literature, participation in national [JDS, MJE, AD, HS] and international [JDS, MJE] groups focused on improving the sustainability of healthcare, and conversations among the multidisciplinary group of authors who are experienced in healthcare informatics [DFS, AD, HS], information technology management [AD], clinical medicine [JDS, HS], and environmental sustainability and engineering [JDS, MJE].

First, IT and healthcare-related equipment and software should be optimized to directly reduce their energy and material consumption.[12] For example, smart automation that allows powering down or turning off equipment or devices that are not expected to be in service can reduce electricity use, as can procuring more energy-efficient equipment.[13] Further, many computing devices are replaced on a schedule that does not necessarily reflect their useful lifespan. Increasing the length of time devices are used before they are replaced can reduce both the materials and energy required to manufacture IT equipment as well as e-waste that must be managed.[14] Second, computing technology should help quantify, control, and monitor energy usage, resource consumption, and waste in the building infrastructure and services that support various aspects of the healthcare delivery enterprise, such as heating, ventilation, air-conditioning (HVAC), and lighting.[15] Third, health IT and especially EHRs should influence resources used in the delivery of clinical care, for example by identifying and facilitating more efficient clinical and administrative processes, and by informing environmentally preferable procurement and clinical decision-making.[11] All 3 principles—use of more efficient IT/equipment, use of IT/equipment to monitor and control energy consumption/waste related to buildings and support services, and use of IT/equipment to influence care delivery and clinical decision-making, should be considered in any informatics-centric approach to promoting decarbonization and environmental sustainability.

In the sections below, we build on these 3 guiding principles, define the field *Clinical Climate Informatics*, and propose an actionable clinical informatics framework to reduce healthcare's environmental pollution and climate-related impacts. The proposed framework, which is derived from an established 8-dimension sociotechnical model,[16] focuses on "Information technology-enabled Clinical cLimate InforMAtics acTions for the Environment" and henceforth titled the "i-CLIMATE Framework." It has 5 actionable components, each of which includes specific considerations and sustainability solutions. We define *Clinical Climate Informatics* as a field that applies data, information, and knowledge management principles to operationalize components of the i-CLIMATE Framework. The framework has a sociotechnical foundation that involves both technical (eg, hardware/software, clinical content, user interface) and nontechnical, social considerations (eg, organizational policies, workflow, work environment, culture, people, external rules, regulations, and policies).[16] We first outline the 5 components of the action framework, their goals, and rationale. We then use these 5 components to organize a set of example actions, discuss the corresponding risks, barriers, and potential unintended consequences that will be faced in implementing these actions, and suggest potential strategies to address them. This conceptual approach can help to advance both knowledge and action for how clinical climate informatics can drive healthcare decarbonization activities toward net-zero emissions, reducing e-waste, promoting responsible resource stewardship, and achieving environmental sustainability.

THE USE OF I-CLIMATE FRAMEWORK TO GUIDE INTERVENTIONS AND ACTIONS

The i-CLIMATE Framework has the following 5 components related to promoting decarbonization activities and reducing e-waste in healthcare (Figure 1).

Create a circular economy for health IT

Goals: reuse, refurbish, repurpose, and recycle

The principles of a circular economy which include the elimination of waste and pollution along with decisions to reuse, refurbish, or repurpose equipment and materials are well-known outside of healthcare, but these ideas need to quickly make their way into clinical informatics and healthcare.[17] For example, in high-income countries, healthcare organizations commonly implement high-end computer hardware and it is generally recommended that they replace the vast majority of these devices every 2–4 years depending on improvements in technology, clinical, or administrative use cases, and budget availability.[14] This rapid turnover in computer equipment ensures that users experience good performance and high reliability necessary for them to run the latest releases of operating systems and application software. By replacing or upgrading key components (eg, power supplies, cooling fans, hard drives, or adding RAM—random access memory) and continuing to use the same hardware longer, an organization can significantly reduce their contribution to product life cycle emissions and the enormous amount of e-waste created every year.[18] In addition, organizations can preferably contract with certified "green" vendors that have take-back programs to ensure repurposing of equipment and components,[17] and take responsibility for recycling materials only when reuse is no longer feasible, rather than throwing materials away.[19–21] When acquiring new, and upgrading existing

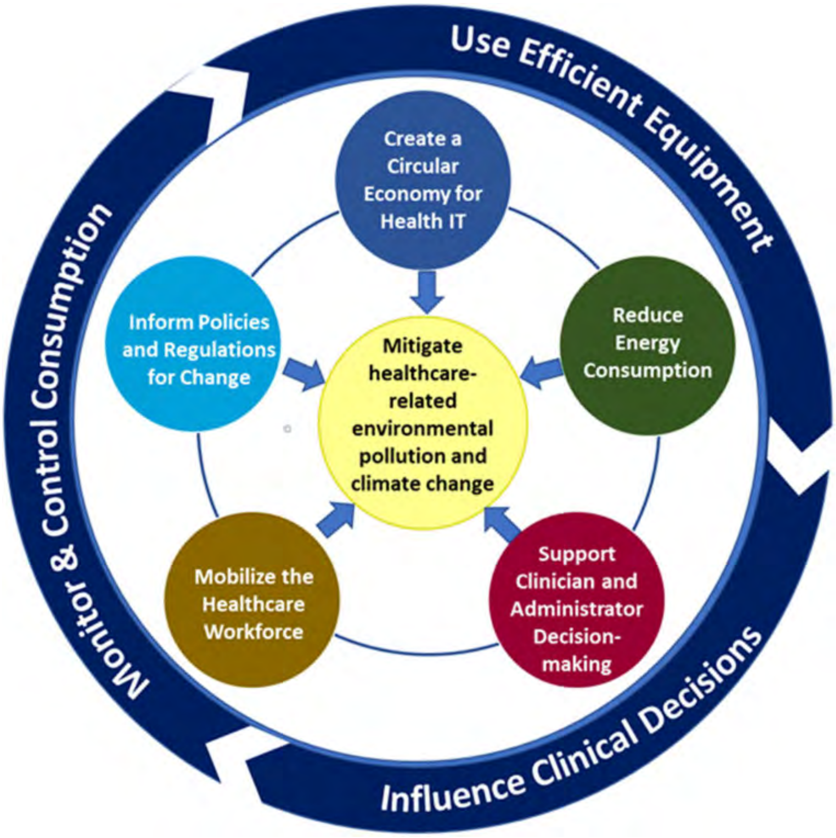

Figure 1. The i-CLIMATE framework and the relationship between the 3 guiding principles and the 5 action components for how clinical informatics can help reduce healthcare's environmental pollution and climate-related impacts.

equipment, Energy Star efficiency ratings should also be prioritized, to maximize energy efficiency.[22]

Reduce energy consumption

Goals: power down, use low-power devices, and increase use of renewable energy

A large healthcare organization uses significant quantities of electricity to run their computers, and HVAC systems required to maintain the climate-controlled environment. By combining administrative data from the EHR (eg, operating room, clinic schedules, or hospital room assignments) with building-level energy and device monitoring software,[15] an organization could identify facility areas, not in use and automatically reduce lighting, ventilation, and power down electronics. Modifying current energy delivery to an "on-demand" model can reduce energy consumption not just related to building and computer use but also other hospital equipment.[23] This would require manufacturers to develop, and healthcare organizations to adopt and use, functionality (eg, electrical submetering and other sensor-based infrastructures[24]) to allow them to monitor their equipment, safely enter a low-power standby mode, and then power up quickly as needed. It may also be possible to improve overall energy efficiency by reducing patient and staff driving, for example, by using telehealth for relatively simple follow-up visits.[25] This will require clinicians, healthcare organizations, and payers to develop and implement guidelines for appropriate use and billing of telehealth services based on patients' conditions and preferences beyond those adopted during recent emergency pandemic conditions.[26]

Support clinician and administrator decision-making

Goals: measure, display, and monitor data and performance improvement

In addition to making changes in the procurement, use, and configuration of the hardware and software itself to address climate change, health IT can also enable clinicians and healthcare administrators to make climate-informed changes in their procurement and work processes.[11]

A primary goal of *Clinical Climate Informatics* is to support more climate-friendly clinical decision-making. Substantial overuse of testing, medications, and supplies is ubiquitous in healthcare.[27] In instances where there are clinical outcomes equipoise, clinicians may reconsider alternatives before prescribing a product with a large carbon footprint or while prescribing similar medications or supplies that have very different carbon footprints.[11] For example, considerable work has been done to assess the impacts of commonly used anesthetic gases isoflurane, desflurane, sevoflurane, and nitrous oxide on climate change.[28,29] Assuming the cooperation and support of EHR vendors, it would be relatively simple to display in real-time the carbon dioxide equivalent impacts of each anesthesia option available to clinicians at the point-of-care, along with more familiar equivalencies such as miles driven,[30] to encourage environmentally preferable choices. Real-time alerts for fresh gas flow rates have been available for over a decade and have demonstrated waste reduction success.[31] Such information displays might serve to nudge clinicians to select anesthetic gases with fewer climate impacts[32] and reduce their overall use.[28]

Using embodied carbon emissions when evaluating the purchase of supplies or equipment is not well known to middle management who make systems-level procurement decisions. For example, SAP recently released its Product Carbon Footprint Analytics tool which provides a means for organizations in select industries to assess the carbon footprint of their devices or supplies across the value chain.[33] Similar tools could be developed to cover the healthcare industry. Health IT could then help by creating organization-wide dashboards that incorporate this type of product lifecycle carbon emissions information to help clinicians and healthcare administrators consider, track, and compare the environmental costs of different supplies, similar to those used to monitor EHR usage,[34] safety,[35] maintenance,[36] or financial costs.[37] Often, displaying and monitoring the actual or relative costs of different options is enough to change behavior.[11]

The EHR can facilitate measuring, displaying, and monitoring information that estimates the effects of various decisions regarding the use of supplies, treatments, or medications on GHGs. Similarly, tracking procurement and supply chain data can provide information on how a healthcare system uses and disposes of supplies. Health IT can be used to track all of the information on use, cleaning, and disposal of different supplies and related work processes. Displaying this information to clinicians and administrators who make decisions about procurement and supply chain management within a healthcare organization can nudge them into better resource stewardship and more carbon-friendly choices.

Mobilize the healthcare workforce

Goals: train, educate, and incentivize

To achieve high impact from the i-CLIMATE Framework, the entire healthcare community should ideally be involved, including informaticians, payers, suppliers, administrators, clinicians, and patients. Most chief information officers (CIO) and chief medical informatics officers (CMIO) are not taught about this in any informatics curriculum even though they control a significant portion of the equipment purchasing and other decisions responsible for generating a significant amount of GHGs, environmental waste, and energy consumption. Most C-suite executives and their boards of directors in healthcare that make key decisions also do not currently have data or information to guide them about climate actions even though they may realize it is an important area to focus on.[38] Informaticians can play a key role here. In addition to ensuring these influential executives can understand quantitative data about the problem, they can communicate how informatics and health IT can make a difference.[39] These concepts apply to administrators and clinicians too. For instance, the CMIO can help educate and support clinicians in their day-to-day decision-making through judicious use of both active and passive clinical decision support within the EHR. Finally, if healthcare organizations included information about their decarbonization activities, efforts to reduce e-waste, and activities to promote responsible resource stewardship and environmental sustainability in their annual reports and community outreach activities, future staff would be able to use this information to help them choose where to work.[40] There is a possibility that climate-conscious patients would also make use of this information when making elective healthcare decisions.[41]

The current climate emergency needs bolder actions and this is also true for clinical informatics. We propose the development of a specific clinical climate informatics curriculum that focuses on use of data, information, and knowledge and their associated principles of management to operationalize the 5 components of the i-CLIMATE Framework. For example, healthcare organizations need new educational content to address the importance of mitigating GHGs and environmental waste in building a sustainable future, along with education on how best to use utilization and emissions data for strategic management within their healthcare delivery system. This latter activity in turn would generate new information on how healthcare organizations could modify existing applications, decisions, devices, and processes to address the problems of climate change. Finally, informaticians can nudge and motivate health system administrators to change by integrating activities for reducing GHGs, energy consumption, or environmental waste with activities already being undertaken as part of existing incentive programs.

Inform policies and regulations for change

Goals: incentivize, motivate, report, and regulate

Ultimately, various types of economic, social, regulatory, and political strategies are needed to effect change. Healthcare organizations spend a tremendous amount of money on computer and networking equipment in addition to utility bills. Better IT-enabled methods still need to be developed to capture and report carbon footprint data. Health IT can also better capture the health-related impact of climate change, for example, through new pollution-related disease classification codes.[42] For example, even though certain conditions (asthma exacerbation from smoke, heat-related illnesses) are precipitated by climate changes and pollution, the current billing codes infrastructure and our EHRs do not accurately account for this. These methods could provide a more powerful data-informed "burning platform" to impact policies and regulations. Furthermore, clinical climate informatics and use of large-scale, integrated electronic data could not only help advance knowledge about the health impacts of climate change but also help understand their mechanisms, enable opportunities to intervene, and provide early warning signals to protect patients and the public.[43] Such climate-related data could be of immense value to policymakers who serve vulnerable populations and communities.

Informatics can enable the data and information that organizations need to exert their economic power to put pressure on IT, utility, and service suppliers to encourage them to "go green." In addition, healthcare organizations and their IT leadership can use this data and information to work with their local, state, and national political representatives to encourage them to enact climate-friendly legislation, including driving rapid shifts to clean power.[44]

i-CLIMATE framework implementation

Given the financial, technical, and personnel constraints that exist in the modern healthcare delivery system, implementing the i-CLIMATE framework will be challenging. However, rapid implementation is critical if we are to make the necessary changes required to meet aggressive climate targets.[45] Currently, work underway in both the National Academy of Medicine Action Collaborative to Decarbonize the U.S. Health Sector[46] and the U.S. Health and Human Services Office of Climate Change and Health Equity[47] could bolster such efforts. Table 1 (below) gives pragmatic examples of actions that could be taken in each of the i-CLIMATE framework's components. With each potential action or intervention designed to reduce energy consumption or environmental pollution, we provide its rationale, potential barriers or risks that implementers may encounter, along with a suggested strategy to address them. Success in implementing these actions will require a concerted effort, attention to potential unintended consequences, a consideration of tradeoffs, and compromise. Implementation thus is a shared re-

Table 1. Operationalizing the i-CLIMATE framework to decarbonize healthcare and reduce environmental pollution

i-Climate framework component	Potential action or intervention	Rationale	Potential barriers or risks	Strategy to address barrier or risk
Circular Health IT Economy	Lengthen replacement cycles for servers and clinical workstations to 4–6 years.	Reduce consumption of natural resources, computer components, and waste generation; save money; save work	Reduced computer performance and reliability	Consider adding RAM to workstations; Make sure devices are free from disk clutter and malware
	Right to update, repair, or replace internal computer hardware components	Reduce downtime; increase supply chain resilience; Save money	Reduced safety and reliability; Often requires reapproval by FDA, Lack of policies to support activities	Adopt Federal Trade Commission recommendations on the "right to repair"[48]
	Contract with take-back programs certified to responsibly repurpose, refurbish, and (lastly) recycle devices[49]	Reduce consumption of resources required to manufacture devices (eg, greenhouse gases used to generate electricity; plastics used in computers, rare earth elements used in computer hardware)	Risk of inadvertent disclosure of protected health information on old disks. Challenge to ensure sustainability claims to avoid greenwashing[50]	Scrub all hard drives and memory before recycling. Mandated standard environmental disclosures. Use certified vendors.
	Encourage health IT-related suppliers to go green	Reduce consumption of resources required to manufacture and dispose of devices, and use safer materials	Suppliers may try to raise prices to accommodate "green" initiatives Greenwashing	Negotiate with multiple suppliers; get competitive bids; Mandated standard environmental disclosures
Reduce Energy Consumption	Use IT to identify unused areas and equipment to power down	Save electricity	Decreased lifespan of devices; increased time to login in the morning; difficult to do nightly updates to software/operating systems	Develop applications to automatically shut down unused devices and restart machines before work starts
	Use low electrical consumption CPUs	Reduce electricity consumption	Slower computers result in longer response times for clinicians	Newer devices should have minimal differences in performance
	Use shared cloud computing resources rather than locally hosted solutions	Savings on electric, heating, cooling resources[51]	Loss of local control; potential increased risk of data breach	Require remote-hosting services to sign a business associate agreement as specified in HIPAA
	Use clean energy sources for data center;	Reduce greenhouse gases and toxic air emissions from fossil fuel combustion used to generate electricity	Underdeveloped high-reliability, clean energy infrastructure	Invest in newer battery technology and solar panels; Work with local utilities to maximize ability to respond to emergencies; encourage state-level policies to drive investments in clean energy
	Optimize algorithms to reduce computational complexity and memory requirements	Reduce computational requirements—save electricity; enable organizations to use smaller computers	Assumes that algorithms are not already optimized.	With a concerted effort, most software can be significantly improved
	Reduction in printed reference books	Increased availability of reference material via computer; Reduced printing costs; Save natural resources	Information not available during power outages;	Work to reduce impact of power outages
	Increased use of telemedicine[52]	Reduce driving for patients	In-person visits are still needed for testing, procedures, and certain treatments. Increased technology and energy requirements.	Develop guidelines for appropriate use of telemedicine services based on patient condition

(continued)

Table 1. continued

i-Climate framework component	Potential action or intervention	Rationale	Potential barriers or risks	Strategy to address barrier or risk
Support Clinical or Administrative Decisions	Alerts to reduce ordering/ use of tests, medications, procedures; Personalized resource consumption and associated emissions reports	Reductions in unnecessary test, medications, procedures; Reduce costs and pollution	Decreased revenue for health system; Increase alert burden for clinicians; Reduction in adherence to other alerts	Use noninterruptive information displays; Work with payors to share cost savings
	Adopt pollution-related disease classification codes[53]	Help improve our understanding of the effects of pollution on health	Insufficient knowledge to utilize existing codes; insufficient codes	Work with clinical content vendors to make codes widely available; advocate for new climate-related diagnosis codes[42]
	Reporting and displaying estimates of carbon-equivalent emissions in EHR, to influence environmentally preferable choices	Increased awareness of the problem; promote change	Increased time, effort, and cost to generate reports; information overload for clinicians; reduced screen space for other clinical information; vendor greenwashing of product and service emissions	Work with EHR vendors to create reports that can be shared across their customer base; governmental emissions reporting standards
	Reporting and displaying estimates of carbon-equivalent measures in procurement databases to influence environmentally preferable choices;	Reduce shipping and handling costs	Potential increase in costs; vendor greenwashing of product and service emissions	Work with suppliers to reduce impact of changes; governmental emissions reporting standards
	Use data analysis to streamline work processes, procedures, and procurement processes (eg, shortest driving routes)	Eliminate waste of supplies; optimize driving and delivery routes	Information gaps and lack of integration.	Many of these services are already commonly available; work with vendors for seamless data integration.
Mobilize workforce	Mobilize healthcare workforce around climate change issues	Increase awareness of the problem; promote change	Reduced time for other important clinical matters	Work to make climate issues part of daily life
Inform policy development	Use IT to control energy consumption of the building (lighting, HVAC)	Decrease energy consumption; save money	Small, short-term impact during periods of change from nonuse to high-intensity usage; nonevidence-based policy barriers around infection control.	Careful attention to transitions should minimize impacts. Rational policies to permit HVAC setbacks.
	Policy changes for Payors to set and incentivize "green" targets for data centers and workstations	Increase awareness of the problem; promote change	Potential to reduce time devoted to other issues; legislative inertia.	This should become commonplace over the next few years; international policy drivers.

sponsibility that involves many stakeholders including clinicians, patients, informaticians, senior IT, and administrative leadership, EHR vendors, policymakers, and the government. Successful implementation will also require a strong scientific foundation that involves implementation and behavioral scientists, especially human factors experts and organizational psychologists, alongside environmental scientists who have experience with similar efforts in other industries.

CONCLUSIONS

The current climate emergency calls for bold involvement from the clinical informatics community. We define a new subfield of biomedical informatics, "Clinical Climate Informatics" that focuses on use of data, information, and knowledge and their associated principles of management to operationalize actions to drive healthcare decarbonization activities toward net-zero emissions, reduce e-waste, and promote environmental sustainability. This field supports implementation of the i-CLIMATE Framework. While the framework is bound to evolve over time, it is currently pragmatic and actionable enough to start creating the much-needed momentum to leverage data, information, knowledge management technologies, and informatics approaches to accelerate healthcare's journey to net-zero emissions. Implementation of this framework using sociotechnical principles[54] which include consideration of hardware and software as well as people involved, their communication patterns, workflows, culture, environment, and external rules and regulations, can help ensure an important role for health IT-enabled healthcare and its practitioners in addressing environmental sustainability and improving planetary health.

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AUTHOR CONTRIBUTIONS

All authors made substantial contributions to the conception of this work. DS wrote the first draft of the manuscript. All authors participated in substantial critical revisions of the manuscript for important intellectual content and approved the final version to be published. All authors agree to be accountable for all aspects of the work.

CONFLICT OF INTEREST STATEMENT

None declared.

DATA AVAILABILITY

All data are incorporated into the article.

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AHA POLICY STATEMENT

Toward Heart-Healthy and Sustainable Cities: A Policy Statement From the American Heart Association

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ABSTRACT: Nearly 56% of the global population lives in cities, with this number expected to increase to 6.6 billion or >70% of the world's population by 2050. Given that cardiometabolic diseases are the leading causes of morbidity and mortality in people living in urban areas, transforming cities and urban provisioning systems (or urban systems) toward health, equity, and economic productivity can enable the dual attainment of climate and health goals. Seven urban provisioning systems that provide food, energy, mobility-connectivity, housing, green infrastructure, water management, and waste management lie at the core of human health, well-being, and sustainability. These provisioning systems transcend city boundaries (eg, demand for food, water, or energy is met by transboundary supply); thus, transforming the entire system is a larger construct than local urban environments. Poorly designed urban provisioning systems are starkly evident worldwide, resulting in unprecedented exposures to adverse cardiometabolic risk factors, including limited physical activity, lack of access to heart-healthy diets, and reduced access to greenery and beneficial social interactions. Transforming urban systems with a cardiometabolic health–first approach could be accomplished through integrated spatial planning, along with addressing current gaps in key urban provisioning systems. Such an approach will help mitigate undesirable environmental exposures and improve cardiovascular and metabolic health while improving planetary health. The purposes of this American Heart Association policy statement are to present a conceptual framework, summarize the evidence base, and outline policy principles for transforming key urban provisioning systems to heart-health and sustainability outcomes.

Key Words: AHA Scientific Statements ■ cardiometabolic risk factors ■ cardiovascular diseases ■ cities ■ environmental exposure ■ health equity ■ policy ■ pollution ■ urban population

By 2050, the global population living in urban areas is projected to increase from 4.4 billion to 6.6 billion people, necessitating the development of new cities and massive investments in urban infrastructure.[1] There is widespread recognition that although cities can serve as engines of economic growth and innovation, a vast majority of them are currently failing this mandate and are not delivering on environmental, health, and equity targets.[2,3] People living in many world cities experience multiscalar health risks[4–6] (eg, households lacking clean cooking fuels, adequate and nutritious food, or safe and structurally sound housing; neighborhoods with limited greenery, parks, and sidewalks, limiting active lifestyles; fossil fuel–based energy and mobility systems that contribute to local and regional air pollution; and limited access to health care and other essential services). Indeed, cities worldwide are ground zero for high levels of light, noise, and heat stress, as well as high levels of air pollution contributed from local sources such as traffic plus long-range pollution from large surrounding industrial facilities and agricultural activities, crop burning in cities, or distant forest fires. Cities also face multiscalar climate risks, including neighborhood-level heat and flooding and larger-scale droughts and other extreme climate events.[7,8] Exposure to toxic chemicals and heavy metals through air, water, and soil pollution poses additional local health risks.

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Populations in cities in the United States and across the globe also face high levels of economic and social inequality. Studies on "pollution inequity," or the difference between environmental health exposures, have shown disproportionately high direct exposure to pollution and climate-related risk factors, resulting in disparities in life expectancy by >15 years between adjacent zip codes.[9] The health effects of air pollution are disproportionately felt by underrepresented races and ethnicities.[10] Recent evidence from redlined neighborhoods in the United States makes a compelling case that the combined effect of adverse environmental exposures and transgenerational social vulnerability, facilitated by institutionalized racial segregation, results in continued poor health outcomes for underrepresented races and ethnicities.[11–13] The greatest burden of chronic noncommunicable diseases is borne by cities, with atherosclerotic cardiovascular disease (ASCVD) and type 2 diabetes contributing to the preponderant majority of deaths and disability globally.

Addressing the diverse and multiscaled social, environmental, and infrastructure risk factors that contribute to cardiometabolic risk in cities by transforming the local environment and transboundary provisioning systems represents a new paradigm for public health and serves as an anchor for this policy statement.[1,3,14,15] Globally, there are 7 key physical provisioning systems that provide food, energy, mobility-connectivity, housing, green infrastructure, water, and waste management and lie at the core of human health, well-being, equity, and sustainability.[5,16] In supporting people living in urban areas, these systems consume >90% of the world's water and generate >94% of global CO_2 emissions, with faulty and inadequate provisioning systems at the root of an estimated 19 million premature deaths annually.[1,17] Estimates drawn from the GBD Study (Global Burden of Disease) highlight the premature mortality due to adverse environmental exposures highly prevalent in cities that result from inadequate and problematic provisioning systems.[18] The preponderance of toxic environmental exposures occurs in urban environments. In 2019, nearly 12 million people died globally as a result of living or working in an unhealthy environment—nearly 1 in 4 of total global deaths. Environmental risk factors such as air, water, and soil pollution; chemical exposures; climate change; and ultraviolet radiation contribute to >100 diseases. ASCVD and risk factors such as hypertension and type 2 diabetes dominate disease burden attributable to environmental pollution. In 2019, nearly 7 million deaths were attributable to the joint effects of household and ambient air pollution globally, whereas 831 502 people died as a result of low physical activity. Nearly 2 million died prematurely as a result of nonoptimal temperatures, with this number projected to increase in the coming years. Even with global warming reaching just 1.5°C, 350 million more people could be exposed to deadly heat stress by 2050, with the number of heat-stressed megacities doubling from today's levels. The results of a World Health Organization study indicate that at least 1 million healthy years of life are lost every year from traffic-related environmental noise in western Europe alone.[19] Estimates for exposures such as lack of green spaces, solid waste, light pollution, and many types of chemical exposures beyond air pollution are currently lacking given the lack of good exposure-response relationships, suggesting that the health impact of many urban exposures is not captured with current frameworks.

Figure 1 presents a social-ecological-infrastructural systems framework rooted in the 7 key provisioning systems previously described.[5,6] This complex system framework encompasses the various factors that are interconnected and interact in various ways.[14] Components of social-ecological-infrastructural systems respond to changes in other components, sometimes triggering feedback that can amplify, reduce, or stabilize effects throughout the whole system. These interconnections and interdependencies, while providing the adaptability and resilience necessary to tackle complex challenges, also render mapping and managing challenges difficult. The framework also highlights the fact that resource requirements transcend city administrative boundaries, reaching far into regional surroundings and global supply networks. Although essential for functional homes and businesses within city boundaries, provisioning systems also generate multiscale climate and health risks, associated with providing heart-healthy food, energy, mobility, and construction materials, both within cities and across the supply chain (transboundary), from extraction of raw materials to their eventual consumption in cities. At the household level, these risks include unhealthy household diets, limited opportunities for physical activity, and exposure to air pollution from indoor sources, especially biomass in many developing countries.[20,21] Poor access to greenery, reduced active mobility, and limited access to nutritious foods and health care are additional factors at the neighborhood level. Last, at the urban-regional level, exposure to air pollution and chemicals, excess temperatures through urban heat islands, and risks for flooding, drought, and forest fires offer increasing risks.

The social-spatial-political design of urban provisioning systems both manifests in and exacerbates social inequalities in cities by class, race, age, and migrant and disability status, translating to vast disparities in exposure to health risks and associated health outcomes. Scientists and policymakers are increasingly recognizing the importance of developing environmentally sustainable cities and provisioning systems that are both equitable and healthy. This new paradigm for improving health, well-being, and sustainability through a focus on key urban physical provisioning systems is increasingly reflected in an emerging robust scientific literature focused on

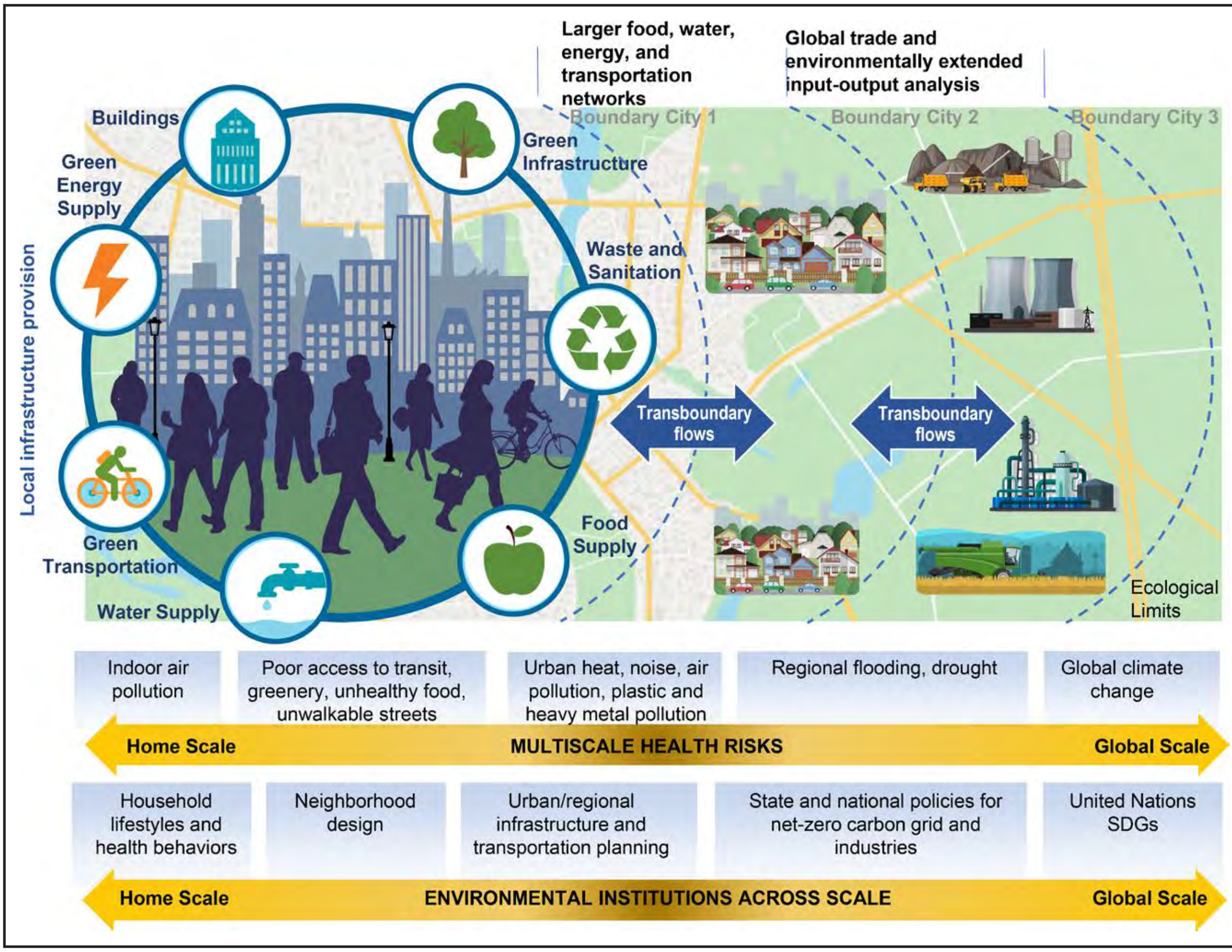

Figure 1. Urban provisioning systems (shown by icons surrounding the city graphic) are decisive for sustainability and health transformation in cities by shaping resource use, affecting exposures, and determining health outcomes.
The transboundary flow of resources and the importance of larger food, water, energy, and transportation networks together with trade cannot be overemphasized. The bottom of the figure details the health risks associated with failure in these provisioning systems. SDGs indicates sustainable development goals. Adapted from Ramaswami et al[5] with permission from AAAS and the Authors.

provisioning systems,[5,6,14,17,22–24] as well as high-level policy frameworks such as the United Nations' sustainable development goals (SDGs) framework, the New Urban Agenda, and the Health in All Policies approach.[23,25–27]

Several recent expert opinions and policy initiatives related to aging infrastructure, low-carbon development, resource-efficient cities, and zero-carbon cities are calling for a transformation of these 7 key provisioning systems that are essential for the functioning of cities.[1,5,17,28] Indeed major investments in infrastructure are already on the horizon, including the Inflation Reduction Act in the United States, which will provide a once-in-a-lifetime opportunity to reform aging provisioning infrastructure.[30,31] These initiatives will drive investment in cleaner power plants, electric mobility, and other greening efforts across cities in the United States and worldwide. Already, >1000 cities have pledged to achieve net-zero carbon emissions by 2050.[32] The accomplishment of net-zero goals by 2050, while requiring significant infrastructure transformations, offers the potential of substantial improvements in heart health. It is critical that the cardiovascular health research community recognize the scale of transformation that is being proposed in zero-carbon transitions and the once-in-a-generation coalescence of opportunities that could be leveraged to create heart-healthy cities (Table 1). However, it is also important to emphasize that even small changes across multiple provisioning systems may have a large impact. Indeed, there is evidence that small changes in individual components of the 7 key systems toward environment and sustainability goals, for example, small increases in walking and bicycling, may improve cardiometabolic health.[33] Overall, transforming key provisioning systems involves the following:

1. Integrated spatial planning of the urban environment that improves access to jobs, key services such as health care, urban parks and greenery, heart-healthy food, safe water, walkable and

Table 1. Opportunities to Create Heart-Healthy Cities

Emerging coconvergent technological innovations for infrastructure (smart grid, electric vehicles, shared mobility) and urban design innovations (eg, urban form and greenery, active transportation infrastructure) that can offer cobenefits for cardiovascular health
Low carbon net-zero carbon agendas in cities (and nations) with reduced fossil fuel emissions with substantial opportunity to reduce air pollution and associated cardiovascular outcomes
Integrated approaches to urban form and 7 key infrastructure and food provisioning systems that, while reducing social inequality, also have the potential for significant cobenefits to heart health
The new science of sustainable urban systems, key principles, and models with potential benefit to reduce chemical exposures and climate risks and to advance well-being from local to global scales
Principles and policies related to cobeneficial/win-win transformations in urban design of infrastructure and food systems that advance both sustainability and heart health

bikeable streets, safe living environments, and solid waste management while reducing the demand for energy and motorized travel;

and

2. Innovations in the transboundary supply of energy, fuels, construction materials, healthy foods, and water that can dramatically reduce regional air pollution and greenhouse gas (GHG) emissions. Examples include power grid transitions toward zero-carbon emissions, mobility transition toward zero-pollution electric vehicles, the emergence of low-carbon sustainable construction materials, strengthened circular economic principles, shift to plant-based diets, and sustainable waste management systems.

The purposes of this policy statement are to present a conceptual framework, summarize the evidence base, and outline policy principles for heart health and sustainable cities. We call for interdisciplinary collaborations among medical and public health professionals, urban planners, infrastructure engineers, and economic development and social justice organizations to fully engage with residents, community stakeholders, and policymakers—spanning from neighborhood to national scales—and to demand and advocate for the implementation of this policy agenda to ensure realization of economic vibrancy, environmental sustainability, social equity, and comprehensive public health.

IN-BOUNDARY AND TRANSBOUNDARY METABOLISM FRAMEWORK FOR HEART-HEALTHY SUSTAINABLE CITIES

Urban metabolism is a useful framework to help define relationships among human activities, resource use, and environmental impacts, both within and beyond the city boundary.[6] Early efforts focused on the city as a whole and defined metabolism as "sum total of the technical and socio-economic processes that occur in cities, resulting in growth, increased demand for energy, water and materials production of value added goods and elimination of waste."[34] As the field expanded, the embodied water use and energy use and the related pollution emitted along the supply chains associated with key infrastructure and food systems were integrated in the form of footprints.[6] Subsequently, the concept of socially differentiated metabolism emerged, exploring how social inequality in access and consumption within cities contributed to disproportionate exposure to pollution often in poor and underrepresented racial and ethnic populations, who have contributed little to these emissions.[35] More recently, the metabolism framework has also been used to assess the potential transition from a linear "take-make-waste" to circular economies that "reduce, repair, reuse, and regenerate." Sustainable circular economies can improve resource efficiency and preserve or regenerate natural resources and capital, providing broad benefits to society, as long as care is taken that any technological processes to extract and recycle resources in and of themselves do not cause inadvertent consequences, including on health.

Cities may have tremendous market power in demanding healthier and more environment-friendly design of key provisioning systems, facilitating a shift toward healthier behaviors and consumption patterns that endorses these choices.[36,37] Given the substantial impact of the urban environment on cardiometabolic health, a better understanding of the locus and scale of interactions between the 7 provisioning systems is needed to advance our understanding of their impact on health. At the same time, it may be necessary to connect the transboundary infrastructures with regional and global environmental and health impact by engaging multiple actors and institutions across multiple scales. Against the backdrop of Figure 1, 2 broad pathways can help enable this transformation of cities to enhance heart health, environmental sustainability, and equity. These 2 pathways and associated specific strategies include the following:

1. Integrated urban spatial design: designing a more compact, green, and inclusive urban environment that reduces demand for energy and motorized travel, regulates urban climate (trees, wetlands), promotes healthy lifestyles, and enables equitable access to health care, employment, and other essential services. When broadly considered, integrated urban spatial planning can be achieved through interventions at 3 scales.
    - The macroscale is generally influenced by metropolitan regional planning done collaboratively with municipal governments, which focuses on the distribution between central cities and suburbs of people (housing); jobs; open and recreational space; essential services such as markets, health care, and emergency services; and public health and civic infrastructure.

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- The mesoscale of networks connecting these various land uses typically consists of highways and feeder road systems, rail and transit networks, pedestrian and bicycle infrastructure such as greenway and trail systems, and on- or near-street facilities. It is heavily influenced by state, regional, and local transportation; public works; and infrastructure agencies.
- The microscale entails street-level and neighborhood design details such as building orientation and access; street layout and safety measures; public space and furnishings; and plantings. It is heavily dependent on local government, infrastructure agencies, and often private sector development entities.

Urban policies in communities may facilitate cardiovascular and metabolic health at all 3 levels and often require collective consideration but are seldom thought of in this manner. Each of these levels of intervention is, by itself and together with the others, important to support physical activity, mobility, and access to nutritious food and transportation and could help mitigate harmful exposures that heighten cardiovascular and metabolic risk. Access to green space, for instance, requires planning and consideration at all 3 levels.[38] The macroscale also requires comprehensive planning, zoning, and development policies that provide for compact development with a mix of land uses so that "live, work, shop, play, learn, grow, and pray" destinations are intermingled, not segregated.[39] The mesoscale requires continuous networks of pedestrian, bicycle, and transit facilities and services connecting these destinations. Seemingly mundane decisions such as sidewalks, on-street bike lanes, and cycle tracks have a profound effect on physical activity. Comprehensive nonmotorized trail networks and reliable low-cost, high-frequency transit appropriate to community size and scale are important.[40,41] At the microscale, the environment must be functional and appealing for users of all ages, incomes, races, abilities, and disabilities. Design attributes, universal access for people of all abilities and disabilities, functional and inviting street furnishings, and safety and traffic-calming measures, all designed with community input, create a microscale that rewards rather than punishes the pedestrian, bicyclist, and transit rider.[42]

2. Supply-side innovations in provisioning systems. Supply-side transitions entail the following:
   - Clean energy and zero-carbon electricity. Several major US utilities are announcing plans to achieve net-zero emissions by 2050.
   - Low-carbon fuels and electric mobility, including investments in renewable fuels and, more recently, proposals to enable full-scale transition to electric vehicles supported by a zero-carbon grid, with several countries such as India and China adopting such goals.
   - Low-carbon sustainable construction materials, including alternative cementitious materials and mass timber construction with potential for reduced embodied carbon and air pollution from the manufacturing, transportation, installation, and disposal of building materials.
   - Local-regional agriculture and sustainable producers supplying supermarkets, small stores, and farmers markets with nutritious food.
   - Green infrastructure and low-stormwater-impact development practices.
   - Water and waste systems transformation.

These sectoral interventions exhibit system effects in that intervening on even a few of these may have nonlinear disproportionate benefits in reducing or even eliminating exposure to a range of cardiometabolic risk factors, including air pollution, noise, light, and extreme heat.[43] For instance, well-designed, more compact urban development can advance active mobility and reduce motorized travel demand and associated tailpipe pollution locally, as well as the demand for cement and other construction materials, producing less regional and local pollution. Reducing red meat consumption not only can benefit health but also can reduce energy use, GHG emissions, and land, water, and fertilizer use associated with the cattle and feed industries that are responsible for regional air pollution. Last, procuring locally sourced foods may help reduce GHG emissions, encourage organic farming approaches, and reduce the reliance on synthetic chemical fertilizers, thereby reducing water contamination and nitrogen/phosphorus loading.

The emerging evidence base and mechanisms by which these transformations individually or collectively affect health are summarized in the following sections. Conceptually, one may begin to consider a complex framework of factors in the urban landscape design and built environment that, together with provisioning systems, may powerfully affect cardiovascular and metabolic health. This includes the material flow of the stocks of energy, nutritious food, and water in a city; political-economic dimensions of institutions, actors, and capital; and how decisions that affect each of these entities drive and interact with each other in determining risk exposures and eventual adverse cardiometabolic health outcomes (Figure 2). Figure 2 depicts how regional planning, urban design decisions, neighborhood layouts, and transport planning decisions directly and indirectly affect health by influencing various health exposures and has been drawn from other similar frameworks.[44] These exposures in turn may affect intermediary pathways, as depicted in Figure 2, that are also mechanisms implicated in response to diverse environmental exposures such as air, light, and noise pollution; exposure to organic chemicals; toxic metals; and social stressors.[8,45–56] The relevance and importance of each of these mechanisms may vary, depending on the type and

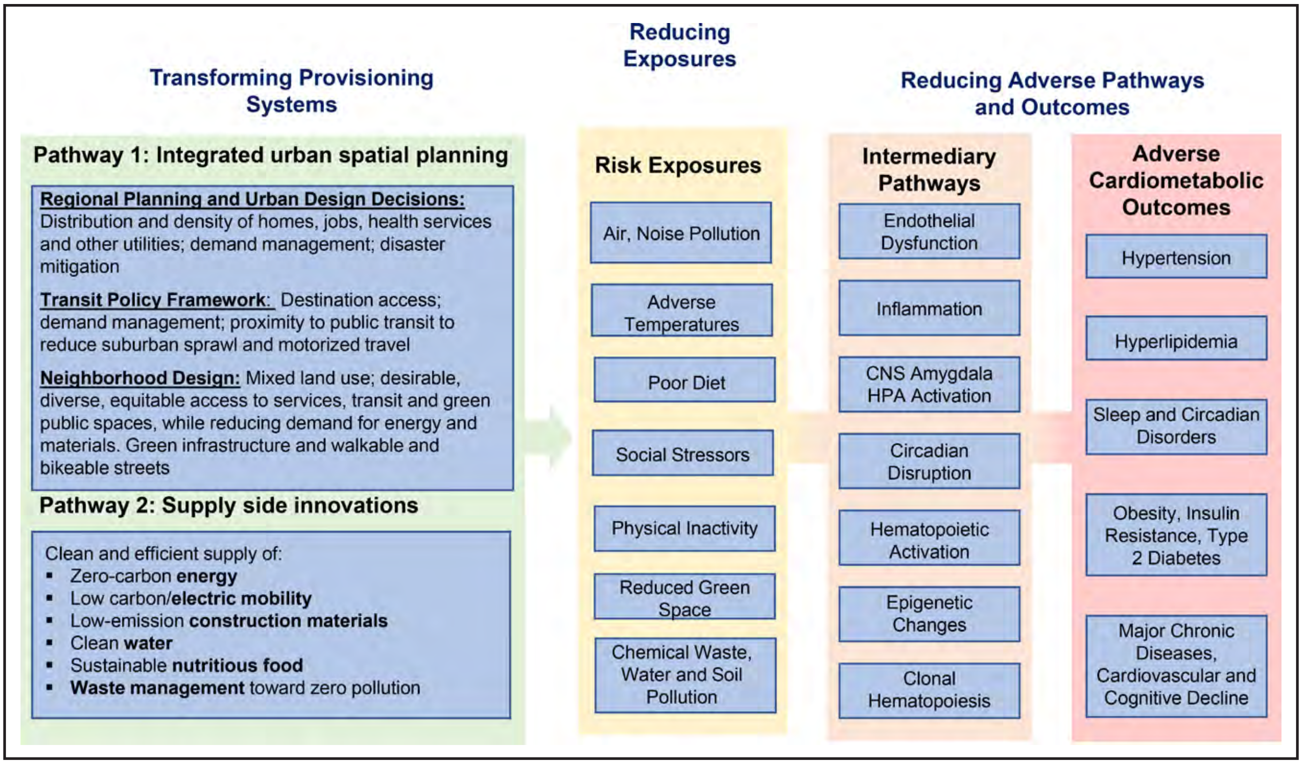

Figure 2. Transforming provisioning systems to reduce cardiometabolic risk exposures and adverse outcomes.
Both known and emerging pathways that determine cardiometabolic risk are highlighted. The graph is read from **left** to **right** with eventual culmination in adverse cardiovascular outcomes on the **right** of the figure with hypothetical intermediary pathways. CNS indicates central nervous system; and HPA, hypothalamo-pituitary-adrenocortical.

duration of exposure, and in many instances, multiple overlapping pathways may be involved. Health impact studies that have begun modeling the impact of modifying risk exposures not only individually but collectively using systems dynamics approaches are helpful in this regard. Such approaches attempt to model the impact of additional human behavior and social factors on complex systems that depend as much on the dynamics of these interactions as they do on individual factors.[57–60] Such an understanding is prerequisite to transforming these systems and curbing resource use and generation of emissions/waste, changes that can result in attainment of equitable cardiometabolic outcomes and climate goals.

PATHWAYS AFFECTING HEART HEALTH AND EVIDENCE

Figure 3 depicts changes in key urban provisioning systems and integrated planning measures with the potential to affect cardiometabolic outcomes in urban environments.

Pathway 1: Integrated Urban Spatial Planning

Prior urban policy and academic research focused on 5 integrated urban design and policy features of density, design, diversity, distance to public transport, and destination access to create cities that promote equitable health. This was subsequently expanded to 8 Ds (those 5 plus the 3 additional features of desirability, distribution of employment, and demand management of transportation) and an expanded framework including 3 additional aspects (destination proximity, disaster mitigation, and distributed interventions) to create 11 integrated urban and transport planning and design opportunities to affect urban health (11 Ds).[61] The original 5 Ds were conceived with the intent to create a framework to influence housing and transport mode, which in turn affects individual, social, and environmental risk factors associated with health and well-being. The additional 6 Ds reflect the importance of these additional variables on health and mitigation of climate change and recognize the impact of city planning on these variables.[61]

Examining the above features in isolation may be less important than collectively viewing these features as a systems framework for heart-healthy cities as conceptualized in the macroscale, mesoscale, and microscale. Indeed, although many of these individual variables have been shown to be powerful drivers of access to resources, employment, and social well-being, interventions must be integrated across the microscale, mesoscale, and macroscale to effect sustainable and heart healthy cities. Population density may provide benefits

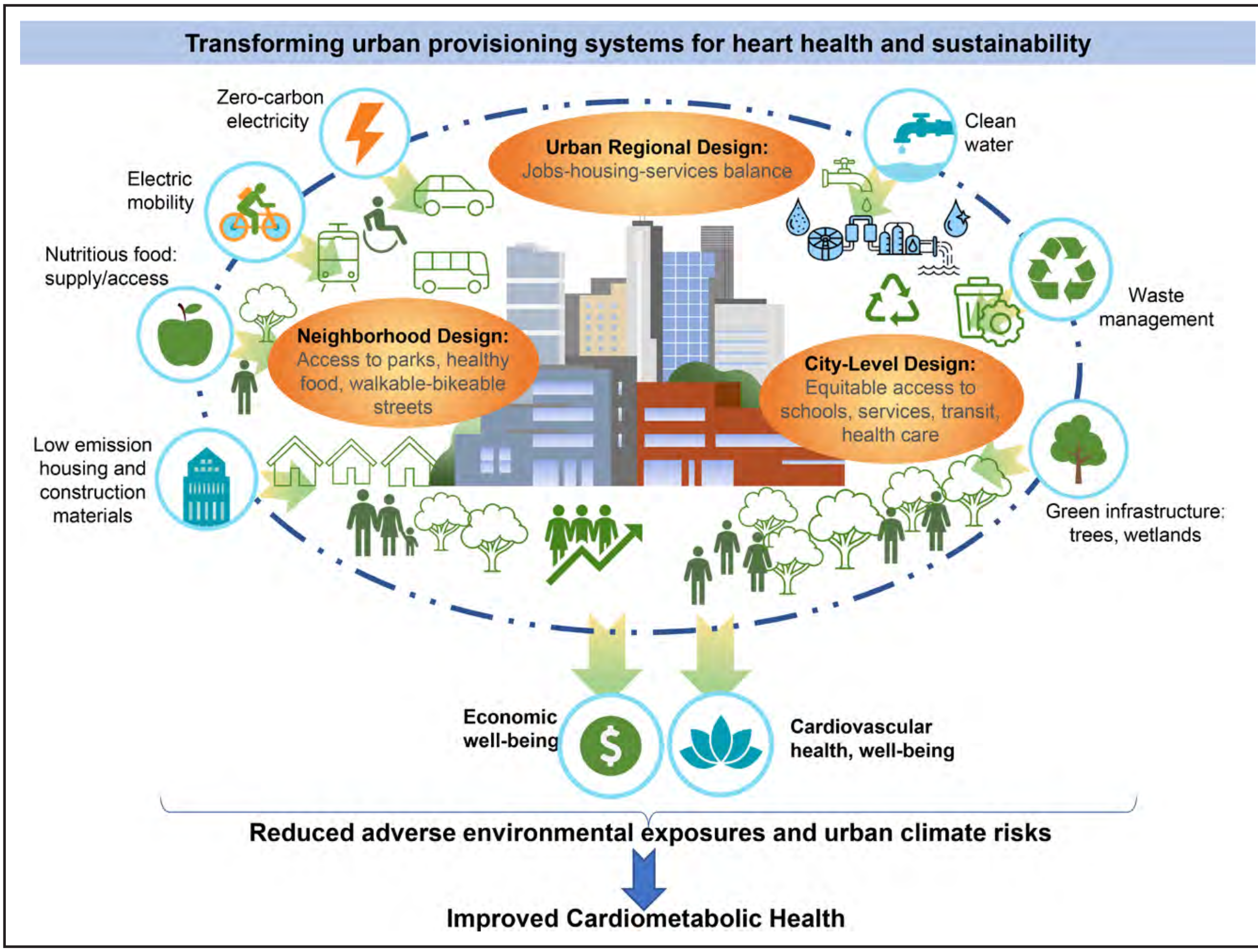

Figure 3. Changes in key urban provisioning systems with potential to affect cardiometabolic outcomes in urban environments.

such as higher wages,[62,63] efficient use of transportation and nontransit infrastructure, energy efficiency, and vibrant street life.[64] A useful predictor of urban demographic density is built-up density. Dense infrastructure and population are typically associated with more walking or mobility-assisted active transport.[65,66] However, increases in population density beyond a certain threshold may deter active mobility without the inclusion of design and diversity to support active mobility.[67] Mixed land use diversity is a design variable most likely to affect the walkability of neighborhoods, primarily by influencing the accessibility and convenience of locations.[68] Nonmotorized commuting (cycling and walking) hinges more on the presence or absence of neighborhood services and retail than on urban density, which may be associated with relatively low vehicle ownership rates and shorter commuting distances among residents of a mixed-use neighborhood.[69,70] In addition, when viewed collectively, each individual measure may provide benefits beyond their intended domains. The optimal blend of integrated urban spatial planning features and policy features may vary according to other complex geospatial terrain features and the underlying cultural and political context.

Overall, good evidence exists for a relationship between multiple urban spatial planning components and cardiometabolic risk factors.[33] A systematic review of 18 studies found that residential density, safety from traffic, recreation facilities, street connectivity, and a highly walkable environment were associated with increased physical activity.[71] Urban spatial planning features may affect not only access to active lifestyles but also social interactions and access to green/public spaces (thanks to mixed land use, connectivity, and walkability), as well as reduced environmental exposures (eg, reduced air pollution and noise) from diminished demand for motorized travel.[72] The cross-sectional IPEN study (International Physical Activity and Environment Network) of 6800 individuals in 14 cities in 10 middle-income and high-income countries found that residential density, public transport density, and park density were independently associated with physical activity. In this study, differences in urban environment were on average responsible for ≈90 of the 150 min/wk of physical activity recommended by the 2018 Physical Activity Guidelines for Americans, concluding that "urban design should be a globally relevant public health priority."[40]

Four environmental attributes significantly and linearly related to physical activity were net residential density, intersection density, public transport density, and number of parks.[40] No prospective studies have examined the impact of urban design elements or land use. Health impact assessment studies have attempted to estimate the health effects, attributable to diabetes and cardiovascular and respiratory disease, arising from alternative land use and transport policy initiatives. In 1 such study in 6 cities (Boston, Copenhagen, Delhi, London, Melbourne, and São Paulo), land use changes were modeled to reflect a compact city in which land use density and diversity were increased and distances to public transport were reduced to produce a modal shift from private motor vehicles to walking, cycling, and public transport. The modeled compact city scenario resulted in health gains for all cities in the prevalence of chronic diseases such as diabetes, cardiovascular disease, and respiratory disease, with the overall health gains ranging from 420 disability-adjusted life-years (DALYs) to 826 disability-adjusted life-years per 100 000 population. New urban models that actively reduce car use, air pollution, and noise and temperature levels and increase exposures to green space and access to places supportive of leisure and recreational physical activity have been reviewed in the Centers for Disease Control and Prevention's guide to community preventive services[74] and the US Surgeon General's Call to Action to Promote Walking and Walkable Communities.[75] A previously published American Heart Association statement provides recommendations and resources to improve transportation systems and provide education to support policies and environments to promote active travel.[76]

Active transportation modes such as walking, biking, and transitioning to active mobility have been shown to have positive effects on cardiometabolic events and risk factors in studies across the world.[33,77–82] Although there are no direct intervention studies, a meta-analysis of 8 studies has suggested a protective effect of active commuting on cardiometabolic outcomes (integrated risk ratio, 0.89 [95% CI, 0.81–0.98]; P=0.016) that was more robust in women.[83] In a large prospective cohort study (n=263 540, 22 sites in the United Kingdom), commuting by cycling and walking was associated with a lower risk of cardiovascular disease, including cardiovascular mortality (cycling hazard ratio, 0.48 [95% CI, 0.25–0.92]; P=0.03; walking hazard ratio, 0.64 [95% CI, 0.45–0.91]; P=0.01), independently of other major measured confounding factors.[84] Quasi-experimental natural studies suggest that switching from private car transportation to active or public transportation was associated with reduced body mass index. Conversely, switching from active or public transport to private motor transport was associated with increased body mass index.[85] Individuals who transitioned from car commuting at baseline to active or public transportation mode at follow-up had a decrease in body mass index of −0.30 kg/m^2 (95% CI, −0.47 to −0.13 kg/m^2; P=0.0005). Conversely, individuals who transitioned from active commuting at baseline to car commuting at follow-up had a body mass index increase of 0.32 kg/m^2 (95% CI, 0.13–0.50 kg/m^2; P=0.008).[86] The health impact of city planning and transport mode choices has been reviewed using prior evidence and systematic reviews when available.[44] Specifically, several indicators from a policy perspective to monitor progress and investment have been identified. These include measures such as percent population living within 400 to 800 m of high-frequency public transport; percent population with employment within ≤30 minutes of their home by walking, cycling, or public transportation; ratio of roads to footpaths; length of designated cycle lanes (miles); and dwellings or area within 0.8 mile of public transport hubs.

Pathway 2: Transforming Provisioning Systems Through Supply-Side Innovations

Supply-side innovations in energy, mobility, nutritious food, housing, green infrastructure, water, and waste management services could potentially have a major impact on health and are reviewed briefly in this section.

Energy and Mobility Sector Transitions

Air pollution from fossil fuel sources, besides accounting for a major fraction of global premature mortality and disability-adjusted life-years, is directly related to climate change through contributions to GHG emissions.[87–90] A large proportion of the deaths due to air pollution have cardiovascular causes.[8,91,92] Globally and in the United States, $PM_{2.5}$ (particles ≤2.5 mm in diameter) is the pollutant of greatest concern, with additional contributions from common air pollutants such as ultrafine particles, ozone, and nitrogen oxide.[8,46,93,94] Air toxins such as formaldehyde and other volatile organic compounds and pollutants such as NO_2 that are secondarily formed in the atmosphere from myriad sources are associated with other toxins that can also exert significant cardiometabolic toxicity.[95–100] Although air pollution is often generated by local sources, a large if not dominant fraction is transported from outside cities, emanating from regional sources such as power plants and biomass burning. Although urban air quality has improved in countries of the Global North, this is not the case in many countries in Asia (eg, India, Nepal), Africa (eg, Nigeria, Ghana), and the Middle East.[21,101] Given the high levels of ambient air pollution in cities in Asia, the Middle East, and Africa, the preponderance of air pollution–related health impact occurs in cities in these regions.[101,102] The largest contributors to total $PM_{2.5}$ concentrations in cities are anthropogenic in origin and include industry, energy transformation, extraction, residential and commercial activities, agricultural fertilizer application, and crop burning. Urban $PM_{2.5}$ can also originate from nonanthropogenic sources such as forest fires.[103–105] In addition, emissions due to construction of roads and building construction may account for ≈30% to 70% of airborne particles in some urban areas.[106] Substantial variability in emission sources is noted across cities, implying that a one-size-fits-all emission source control approach to air quality management is unlikely to work across all urban areas. Instead, management practices should consider local context and local source emission inventories and integrated multisectorial measures of air pollution management, including supply-side innovations. Given that transportation, power, and industry are generally the 3 largest sources of air pollution, reducing tailpipe emissions from fossil fuel combustion engines by rapidly transitioning to electric vehicles and decarbonizing power plants (eg, by limiting fossil fuel–emitting sources in cities through legislation and taxation) may have substantial impact in urban environments. Reducing ambient air pollution may also substantially affect indoor air quality, especially in environments where air conditioning is not in use.[49] In addition to reducing air pollution, electric vehicles are expected to substantially reduce noise in urban areas, although noise levels may increase at highway speeds for electric vehicles. Several electric utilities have committed to net-zero goals, providing carbon-free electricity by the year 2040 or 2050. This effectively implies the phaseout of coal power plants in the United States by 2030, transition to electrifying heat through heat pumps to advance efficiency, and reduction in natural gas use in the heating sector.[28,31,107] The recent Net-Zero America Project showed substantial anticipated reductions in air pollution–related deaths arising from such a systemic transformation of the energy sector.[60] Cost-effectiveness and cost-benefit analyses of energy transition and low/zero carbon energy interventions have relied mostly on the health impact of reducing air pollution to demonstrate economic benefits, making a compelling case for directly targeting such interventions in urban settings.[31,108] Modeling of vehicle electrification in a future zero-carbon grid, for instance, demonstrates substantial health benefits resulting from reductions in $PM_{2.5}$ and ozone pollution, particularly in urban areas.[60,109] Given the individual pollutant health impact framework in which most pollutant exposures have been studied and modeled, there is a paucity of systems impact studies of changing aggregate exposures.

Urban-Regional Food Systems

Unhealthy diets in urban environments pose a greater risk to morbidity and mortality than many other risk factors, including drugs, tobacco, and alcohol use and physical inactivity combined.[110,111] Given that many risk factors are tied to the demand, supply, and consumption of foods in cities, a transformation of urban food systems is urgently needed.[111–115] Nearly one-third of all food produced for human consumption is lost or wasted.[116,117] Food waste and green waste make up more than one-third of all municipal waste, which may be a significant expense for many local administrations.[114] Although global food system transitions have enabled affordable diets, they have had less favorable outcomes for nutritious foods, environmental health, inclusion, and equity.[111,115]

Urban food system–related cardiometabolic risk includes institutional and commercial procurement, supply and eventual consumption of unhealthy diet quality (including diets high in saturated fat, processed meats, sugar, and sodium and low in fruits, vegetables, and other minimally processed foods),[118,119] and food and nutrition insecurity.[111,120,121] Exposures from food production and distribution, both within and outside city limits, also contribute to the health impact of urban food systems. These may include mental health stresses related to high-stress/low-paying jobs in the food industry[122,123] and exposures to air emissions from food transport and production.[124] Indeed, agricultural production in the United States results in 17 900 annual air quality–related deaths, 15 900 of which are from food production.[125] Of those, 80% are attributable to animal-based foods, both directly from animal production and indirectly from growing animal feed.[125] Many city food action plans focus on multilayered levers, some addressing the demand side through dietary interventions, others addressing food and nutrition insecurity and supply chain disruptions, and a third set of strategies addressing food supply through diverse mechanisms, including school lunch meals, procurement, food service guidelines, standards in workplaces, promotion of urban gardening, community-supported agriculture, and farmers markets, which connect local-regional food producers with consumers living in urban areas.[37,126–133] The evidence is clear that neighborhood racial and socioeconomic disparities are also associated with disparities in access to nutritious foods, the density of convenience stores selling unhealthy foods, and the extent of outdoor food product marketing.[134,135] Studies have been mixed, however, on how access to nutritious food may affect diet quality[136,137] and shape cardiometabolic and other health outcomes.[138–143] The density of outlets selling unhealthy foods may be more important than the availability of nutritious foods. Supermarkets in particular sell both nutrient-dense and nutrient-poor foods, and many factors beyond food purchasing location contribute to consumer choices. Furthermore, even consumers with low incomes and low vehicle access frequently travel to the supermarkets they prefer. Nonetheless, reduced access does entail marked increase in time, effort, and expense required to procure healthy diets.[140,141]

Urban agriculture has become widespread, including household gardening, community gardens, and urban farms oriented toward education, food equity, mobile farm markets, and market production.[144] Some deliver foods in underresourced neighborhoods that lack grocery stores and to restaurants serving healthy foods.[145]

Although urban agriculture in select cities has been suggested to be capable of supplying a considerable portion of fruits and vegetables, the cost of land and limitations in many urban environments may limit their impact.[146] At a regional scale, farmers markets are being promoted to connect sustainable regional food production with local consumers. Urban agriculture can improve diet healthfulness,[147] and urban gardening participation has been associated with physical activity and fiber intake,[148] although more study and outcomes assessment are needed to demonstrate the nutritional benefits of these interventions. Recent guidance developed by the United Nations, the Food and Agriculture Organization, and other organizations describes how urban food systems can be designed to achieve multiple sustainability and health outcomes.[114]

Green Infrastructure and Urban Heat Stress

Rising temperatures in cities are expected to exacerbate a range of health impacts, with many studies demonstrating a link between temperature extremes and health, including ASCVD end points.[7,13,88,149] Urban heat islands result from increased use of light-absorbing materials and reduced greenery and can lead to temperature increases of up to about 8°F. Green infrastructure includes various nature-based solutions being deployed in conjunction with conventional "gray" infrastructure in communities. In urban environments, this may include larger green infrastructure such as areas of tree canopy, landscape patches, and green corridors but also smaller representations of nature (eg, green roofs, bioswales) that provide health-supporting benefits. Several prior meta-analyses and studies have suggested an association between green space and health benefits.[150–152] It should be noted that in studies examining a link between green space and health outcomes, the distinction between natural green space and green infrastructure is not always clear.[153] Results of several recent studies have shown that residential proximity to green spaces is associated with a decrease in the risk of cardiovascular mortality and major adverse cardiovascular events.[154,155] In a large cohort-based population study, an increase in residential greenness has been reported to be associated with a decrease in both incident acute myocardial infarction and incident heart failure, and residential greenness has been linked to a 10% decrease in cardiovascular mortality.[156] Individuals living in greener neighborhoods have also been reported to have a 5% to 7% lower relative hazard of developing ASCVD.[157] The mechanisms by which green spaces exert cardiovascular benefits remain unclear, but emerging evidence supports several potential pathways.[153] In a small study of participants at risk of ASCVD, arterial stiffness was positively associated with short-term exposure to ambient $PM_{2.5}$ and ozone and inversely associated with greenness. The association between pollution and arterial stiffness was attenuated in areas of high greenness, suggesting that green neighborhoods can lessen the adverse cardiovascular effects of air pollution.[158] Living in areas of high greenness is associated with lower levels of oxidative stress, higher angiogenic capacity, and lower sympathetic activation.[159] The last may be linked to the well-described psychological benefits of greenery: Those who live in greener neighborhoods report better mental health and lower levels of anxiety and depression, conditions common in urban environments.[160] Green spaces could lower exposure to volatile organic compounds and attenuate the effects of PM and ozone on vascular function.[161] Residential greenness could also increase exercise-related physical activity and may help improve indoor air quality.[153,155] Substantial social inequality in tree canopy has been observed by both income and race; hence, equitable design of green infrastructure will be important to advance heart health.[12,162] Thus, taken together, extant evidence, although largely ecological and associative, supports the notion that green surroundings create healthy urban environments and that living in areas of high greenness is associated with a decrease in the risk of ASCVD and mortality.[155]

Green infrastructure and urban greenery as an intervention may help mitigate urban heat. Green roofs and walls have the potential to attenuate indoor temperatures, improve air quality, muffle noise, and reduce flooding, among other benefits, but there are no studies linking them to cardiometabolic health.[153] Comprehensive city heat action plans can save lives during the harsh summers or in heat islands.[163] Urban reforestation efforts could have a major impact, at least according to modeling studies. Results of a study of 93 European cities suggest that increasing tree coverage by 30% for each city and from the European average of 15% to 30% can lower the temperature in cities by 0.4°C and health-related deaths by 39.5%.[164] Potential approaches to reduce urban heat islands include expanding green spaces, whitening, and other material changes.[165,166] Such strategies have been found to have potential health benefits.[166,167]

Water Supply and Waste Management

The World Health Organization has highlighted the importance of safe, equitable access to water and the health risks associated with the inadequate disposal of solid waste for affected populations.[168,169] The unsustainability of current water systems is increasingly apparent in cities across the world where a growing population is placing tremendous pressure on urban water supplies.[170] Exposure to various chemicals and metals in water has long been implicated in the causation of cancer and neurobehavioral and renal disease and is now increasingly linked to increased cardiovascular disease risk.[8,110] Even low-level exposure to metals that could occur through water has been associated with adverse cardiometabolic outcomes; exposure to lead has been linked to hypertension and arsenic and cadmium to stroke and atherosclerotic outcomes.[50,171–173] Urban water management includes the core centralized services of provision of safe drinking water, urban hygiene (for the purpose of public health), and protection against flooding, complemented by water pollution control. Critical water infrastructure for cities is often obsolete and decaying, with water sources to many cities inadequately protected from nonpoint sources of pollution from agriculture and urban development. Further public and private water agencies are not adequately monitoring and enforcing existing laws and regulations.[174] Addressing water challenges in urban areas requires consistent management and empowered institutions. In the United States, a range of federal agencies or departments have overlapping responsibilities for fresh water.[174] There is a critical need to reorganize and streamline the diverse water responsibilities and laws, especially in the nexus of energy and food policies. Urban water use can be made far more efficient with technologies, rain water harvesting in cities, policy tools, efficiency standards, and tax code revisions that promote water-efficiency investments for industry and communities. A soft water path, in which alternative renewable, smaller-scale, decentralized sources of water for mixed use are combined with improved end-use efficiency and in which ecological and social measures are considered, has been advocated.[170] This includes a shift from a focus on traditional sources of supply that are increasingly costly or simply unavailable to alternative sources such as the reuse of high-quality treated wastewater. Modern water treatment technologies, which can include combinations of chemical, biological, and physical processes, are able to produce water of the purest quality with the health risk from potable reuse of treated wastewater significantly lower than the risk from conventionally treated water.

Poor disposal of waste can pose risks to heart health through air pollution (from open burning of household solid waste still prevalent in many world cities) and exposure to toxins by virtue of living near dump sites in many low- and middle-income countries. Many areas within and around cities in low- and middle-income countries are dumping sites for electronic waste, a major reason for lead toxicity in children. Furthermore, exposure to heavy metals such as lead and cadmium occurs routinely in many underprivileged communities through water and is a legacy of archaic urban water infrastructure and exposure to industrial waste in urban polluted sites.[8,50,175] In general, waste management practices tend to improve as countries move from lower income to higher income levels. As a consequence, the related health risks tend to be greater in low-income countries, where dangerous practices such as open dumping and uncontrolled burning of solid waste are still common, resulting in variegated exposures. The Federal Infrastructure Investment and Jobs Act signed into law in 2021 includes a $55 million investment for clean water and the elimination of lead service lines in the United States. Recent studies show evidence of health impacts from exposure or proximity to disposal sites such as landfills, dumpsites, incinerators, open waste burning, recycling sites, and composting plants.[176] Exposure to lead at toxic waste sites in Latin American countries has been linked to ASCVD risk,[177] and exposure to hydrogen sulfide from landfills has been associated with increased cardiovascular hospital admissions.[178] Many exposures to chemicals, toxic metals, and radiation particularly prevalent in socioeconomically disadvantaged communities are the result of their proximity to legacy waste management sites in cities. Plastic and plastic-associated chemicals are also ubiquitous in urban environments, with many that are endocrine disruptors associated with increased risks of diabetes and obesity. These chemicals have been covered extensively in prior reviews.[179] Single-use and short-lived plastics account for 35% to 40% of current plastic production and are pervasive in urban environments. Plastic disposal is highly inefficient, with recovery and recycling rates below 10% globally. During use and in disposal, plastics release toxic chemicals, including carcinogens, neurotoxicants, and endocrine disruptors such as phthalates, bisphenols, perfluoroalkyl and polyfluoroalkyl substances, organophosphate flame retardants, and residual monomers, into the environment.[179] Macroplastic and microplastic degradation products are ubiquitous in water supplies and are found in hundreds of species. The fate of smaller microplastic and nanoplastic particles (<10 μm) in aquatic environments is poorly understood, but the potential for harm is worrying, given their mobility in biological systems. Limits on plastic use and mandates for recycling could be particularly impactful in urban environments.[180] Some states in the United States have proposed minimum recycled content mandates to end plastic pollution, similar to actions by the European Commission to set quotas for minimum recycled content in new plastic products. The recycling of plastics is a key priority for the new National Framework for Advancing the US Recycling System.[181] Although these efforts are important early steps, a global evidence-based strategy that includes practical and measurable interventions aimed at reducing plastic pollution may be of enormous value.[180,182] The Minderoo-Monaco Commission on Plastics and Human Health is an important step in the right direction.[179]

HEALTH CARE ORGANIZATIONS EMISSIONS AND WASTE

Health care organizations (HCOs) and access to health care and facilities may be considered critical urban spatial planning features. The contribution of HCOs to GHGs and solutions have been the focus of many studies, including that by the National Academy of Medicine.[183–185] HCOs contribute between 5% and 10% of GHGs mainly through their Scope 3 footprint. HCOs contribute not only to GHGs but also to environmental pollution and waste in many cities.[183,185] The outbreak of COVID-19 (coronavirus disease 2019) and other health calamities has further driven increased use of medical protective equipment, takeout meals, and home-delivered groceries, exacerbating the accumulation of plastic waste and pollution in urban environments.[186] It is well acknowledged that HCOs could lead the way in urban transformation, given their influence and, through their engagement, could facilitate changes in urban provisioning systems through leadership and emphasis on health.[185] Interventions such as avoiding hospital food waste, improving recycling, composting, managing solid waste, procuring sustainable and low-carbon diets, solarizing health systems, and using telemedicine could substantially reduce the pollution footprint in urban environments.

POLICY GUIDANCE

A new strategy for urbanization, resource efficiency, and social inclusion based on health at the core of urban development strategies is needed. Two global milestones have endorsed the idea that urban policies are in fact key public health interventions. The first is the 2030 Sustainable Development Agenda, comprising 17 SDGs and 169 targets, with a global geographical scope.[187] The second is the adoption in 2016 of the New Urban Agenda at Habitat III, the United Nations Conference on Housing and Sustainable Urban Development.[188] Based on a new analysis using a previously described framework, a comprehensive Urban Health Framework has expanded and explicitly linked 48 SDG targets corresponding to 15 SDGs as a way of linking the SDG framework with urban decision-making.[26] This framing provides an opportunity to formulate and implement policies with a Health in All Policies approach, which seeks to ensure that health implications are central to all policy decisions and to avoid harmful health impacts in order to improve population health and health equity. Intersectoral work, health equity, governance, and stakeholder participation are key cross-cutting issues in sustainable urban development endeavors. Many cities, especially in the developing world, do not have specific and measurable policy targets to achieve ambitions of being sustainable cities. Measurable policy targets for urban design and transport features are often absent, with policies inconsistent with the evidence, risking committing cities to unhealthy and unsustainable urban systems.[189] Health is an afterthought in most national urban planning policy and is mostly nonexistent in national urban policy documents from lower- and middle-income countries.[189,190] Multitiered policies at the national, state, city, and regional levels; for neighborhoods; and for households are needed. These include specific sectoral policies related to land use and spatial planning and the 7 provisioning systems.

A number of coalitions around the world are starting to mobilize attention on urban redesign with a view to bring sustainable frameworks. For instance, C40 is a network of mayors of nearly 100 world-leading cities collaborating to mitigate the climate crisis.[191] The Resilient Cities Network legacy, built on the 100 Resilient Cities initiative pioneered by The Rockefeller Foundation, focuses on a portfolio of urban resilience in cities.[192] ICLEI, Local Governments for Sustainability, is a global network of >2500 local and regional governments committed to sustainable urban development.[193] Active in >125 countries, the network collaborates on sustainability policy and local actions to lower emissions and to develop nature-based, equitable, resilient, and circular development in cities. The Milan Urban Food Policy Pact is an international agreement of mayors that provides a framework for action aimed at tackling urban food-related issues with 37 recommended actions clustered in 6 categories.[194] For each recommended action, there are specific indicators to monitor progress.[194] There has been progress in China toward policies for healthy cities, although this has been markedly uneven. A recent assessment acknowledges the challenges in Chinese cities and the lack of good data and tools to accomplish these changes.[195] The availability of the city's health profile and health milestones is an obligatory component of the Healthy Cities approach. The importance of engaging all stakeholders to work across sectors for population health improvement also cannot be overemphasized. The individual citizen to the entire multisectoral city management structure needs to be integrated into a single system geared toward maximizing local health outcomes. The attainment of healthy city goals requires strong, consistent political leadership and community engagement.

An important area that could aid policy development is modeled impact of interventions. Health impact assessment studies may allow full assessment of the health impact of plans and projects using quantitative, qualitative, and participatory techniques and could facilitate cost-effective decision-making. Health impact assessments have hitherto not been used effectively in urban planning at the city level, especially modeled after stakeholder needs and vision.[196] Several health impact assessment studies have estimated mortality impact and health costs associated with reduction in environmental exposures directly attributable to energy transitions, increases in green space, improved nutrition and physical activity, and urban interventions, including expansion of cycling networks and access to greenery and public transportation.[164,197–199] For example, the World Health Organization's Health Economic Assessment Tool for walking and bicycling estimates the health and economic impacts of walking and cycling on premature mortality in an integrated manner through changes in physical activity levels, exposure to air pollution while walking or cycling, and risk of fatal crashes in traffic.[200] There is also a dearth of community-based participatory research to identify urban hotspots wherein improved urban provisioning systems can be tactfully deployed to create heart-healthy cities and to reduce pollution exposure. The Tsinghua-Lancet Commission on Healthy Cities in China aimed to understand and address urban health challenges in China's cities.[201] Experts from various disciplines examined environmental and social determinants of health, identified stakeholders, and formulated actions for the prevention, management, and control of adverse health outcomes in cities. Formulation of a national policy, the Healthy China 2030 plan, released by the State Council of China on October 25, 2016, was an important part of a strong unifying message. The plan calls for promotion of healthy lifestyles, optimization of health services, improvements in health care coverage, provision and protection of a healthy environment, and development of service industries in health care. Improving transparency in environmental governance and metrics is apparent at least in the area of air pollution in China. China has also embarked on the world's most ambitious energy transition and is rapidly making progress toward a low-carbon economy. The guiding principles of China's healthy cities that are also applicable broadly to all urban environments include the following: (1) integrate health into all policies; (2) increase participation of residents, the private sector, nongovernmental organizations, and community groups in health management; (3) promote intersectoral action in the design, building, and management of healthy cities; (4) set local goals and assess progress periodically (indicator systems should be put in place to assess progress and inform the public); and (5) encourage academic and private partnerships to support research and education to create healthy cities.[201]

Table 2 provides a rough index of potential options to guide policy and areas where the cardiovascular community can help influence and take the lead. The American Heart Association is further committed to the following principles to facilitate consideration of the cardiovascular and metabolic impact of urban design and provisioning system changes:

1. Helping facilitate consideration of the cardiovascular and metabolic impact of sustainability transitions through coordinating/supporting sustainability policy efforts at all levels of government across urban design and energy, transportation, and food and water/waste sectors, with attention to equity. This includes supporting low-carbon, clean energy, green infrastructure, and decarbonization plans at the national, state, metro, and city levels and engaging with communities to disseminate awareness of the synergies between these goals and heart health.
2. Building partnerships at the national, state, and local levels and between government agencies, the private sector, nongovernmental organizations, and community-based organizations to achieve equity-focused, evidence-based impactful urban public policy. These collaborations should prioritize stakeholder engagement and buy-in to address sustainability planning that achieves climate-resilient provisioning systems and reduction of detrimental exposures to communities. Unifying policies through joint efforts and collaboration among the ministries of health, energy, transportation, labor, education, finance, and women's and children's health will be necessary to accomplish Health in All Policies.
3. Providing support for health impact assessment tools with cardiovascular end points to consider the adverse health effects of changing environments, particularly the effects of inequity, and complex, multipollutant urban exposures and their impact on cardiovascular health.
4. Creating new models within specific cultural, social, economic, and geographic contexts and obtain new empirical evidence to guide the development of equitable, sustainable and healthy cities.
5. Advancing integrated community-based civic participatory efforts that holistically integrate health goals, environment, sustainability, and equity goals research to address the needs of underresourced communities vis-á-vis the equitable access to multiple provisioning systems; reducing multipollutant exposures; and supporting heart-healthy and environment-friendly lifestyles through supportive urban design and policy.
6. Promoting education and outreach to physicians and the general public on developing and disseminating evidence-based design guidelines to advance heart-healthy sustainable cities and educating people on how sustainability in urban environments can promote cardiovascular health.
7. Setting behavior change communication as an important goal for reducing urban footprint and using cost-effectiveness analysis and meaningful engagement of policymakers as part of the mix in combating environmental pollution/climate change.
8. Helping train the next generation of physicians and an advocacy workforce to ensure cardiovascular health in all urban policy decisions and to incorporate a health-first approach.

CONCLUSIONS

The primary purpose of this policy statement is to highlight the importance of moving toward heart and brain health in sustainable cities as ground zero for transforming global population health. Urban cardiometabolic health is driven by complex interactions of a multitude of factors and stakeholders, which can best be described from a social-ecological-infrastructural systems framework rooted in 7 key provisioning systems. Changes within the city and across the transboundary supply networks that bring electricity, nutritious food, fuels, water, and construction

Table 2. Public Policy Solutions to Address Urban Environments for Cardiovascular Health at Different Levels of Government

Issue	Principle or pathway to support heart health	Exposures affected	Examples of specific public policy solutions	Level of government
Integrated spatial planning	Integrating land use planning and transportation planning departments	Air pollution, noise, green space, and stress	Adoption of comprehensive (growth, master) plans, zoning and development ordinances and regulations, and (critically) permitting practices that prioritize: 1. Compact and mixed development patterns 2. Inclusion of diverse and affordable residential stock proximate to essential needs, services, employment, and green space 3. Reduction of sprawl and protection of open space and high-value arable land, especially land that can provide quality food to people living in nearby urban areas 4. Permanent protection of critical water resources	Local, regional
	Metropolitan planning for transit-oriented development stimulates active mobility and equitable access to green/public spaces and health care facilities. Integrate Complete Streets policies in all roadway construction, repair, and maintenance Cardiovascular health as an explicit city planning goal can highlight its importance. Few cities have explicit health-focused actions in national transport policy.	Physical activity through increased active transportation (walk, bike, transit) and recreational walking and cycling	Planning and transport agencies to award infrastructure funding according to the following: 1. Compact development communities and mixed land use areas 2. Full accommodation of active transport modes (walk, bike, and transit) and targeted reduction in motorized vehicle miles traveled 3. Exceptional service to vulnerable (and often historically neglected) populations based on age, race, ethnicity, income, sex, disability, car ownership, health status Adoption of prescriptive Complete Streets policies that: 1. Require context appropriate accommodation of all modes (walk, bike, transit, motor vehicle) in all roadway projects 2. Adoption of state-of-the-art multimodal design guidance (eg, the US National Association of City Transportation Officials design guides) 3. Application of Complete Streets design principles in routine painting and maintenance programs 4. Explicit and rigorous requirements limiting exceptions to fully multimodal designs	Local, regional, state LocalLocal, regional, state, national
Mixed use				
Connectivity	Requirements for street connectivity, pedestrian and cycling infrastructure, access to public open spaces (including parks)	Physical activity through increased active transportation (walk, bike, transit) and recreational walking and cycling	1. Access to public transportation within easy walkable distances 2. Active transportation options that are convenient 3. Mandatory laws promoting open access recreational areas to promote physical activity 4. Taxes on private transport and restricted-access streets	Local
Zoning provisions	Consider enabling language to encourage urban agriculture. Although zoning codes are often not written to specifically prohibit urban agricultural activities, the absence of express permission deters potential growers.	Access to healthy food sources through more equitable, mixed development patterns	1. Specify where and how city and public land can be used for personal or community food production 2. Allow onsite sale of healthy fresh produce 3. Establish urban garden district 4. Provide incentives for urban farming and public green space	Local
Provisioning systems				
Energy sector	Transitioning energy systems toward clean energy and low-carbon goals to reduce air pollution	Air pollution, noise, green space, and stress	1. Public investment in renewable energy at the local and regional levels 2. Develop and implement strategies to phase out coal-fired power plants by 2030 3. Support transitions to electric mobility and heating systems linked to low carbon supply 4. Provide deep incentives for climate technologies that support mitigation and resilience 5. Update and implement current federal ambient air quality standards from the current 12 μg/m^3 annually to <10 μg/m^3	Local, state, federal

(*Continued*)

Table 2. Continued

Issue	Principle or pathway to support heart health	Exposures affected	Examples of specific public policy solutions	Level of government
Energy access in cities and decarbonization	Integrated electrification strategies and planning program. Technical assistance and operational support to governments for geospatial electrification planning, pipeline development and implementation, preparation and minigrid investment portfolios Improving global electrification platform and applications Developing data standards for electrification planning in coordination with key partners	Air pollution	1. Facilitating clean energy access in cities through financial incentives 2. Improving energy grids and decentralizing energy infrastructure 3. Increasing electric car charging outlets	Local, state, federal
Mobility Active transportation Demand management	Encouraging physical activity Participation targets for walking and cycling (eg, percentage mode share) Managing the demand for car travel influences the appeal of driving relative to other transport modes, with consequences for health	Air pollution and reduced mobility Reduced exercise, social stress Air pollution	1. Active transport alternatives; high-volume and efficient active transportation alternatives such as high-volume pedestrian walkways 2. Congestion pricing: introduce congestion pricing to discourage car use during peak hours; use revenue generated to fund public transportation and active transport 3. Carpooling and ridesharing incentives: incentives for carpooling and ridesharing such as preferential parking or reduced tolls 4. Park-and-ride facilities: develop park-and-ride facilities to encourage public transportation for the final leg	Local, state, federal
Urban mobility Policy decisions for connecting the city	Options for formalizing existing transport systems and trade-offs	Increased physical activity through increased active transport modes Reduced congestion, air, and noise pollution; reduced stress	1. Comprehensive transportation demand management programs and policies that shift behavior toward routine walking, cycling, and transit use and away from single-occupancy vehicles 2. Worksite and school incentives for the use of the active modes such as financial rewards, subsidized/free transit, schedule flexibility, elimination of free parking, and accommodations for bicycle commuters 3. Urban policies such as congestion pricing of roadways and parking, urban mobility aids (shared bikes and scooters), decoupling parking from development requirements, and planning for complementary parking uses	Local, regional
Distance to transit/destination	Decreasing distance between transit and destination (15 or 30 min) and enabling active modes to access transit choices		1. Enact guidelines for easy-access cities where people can conveniently access jobs and services within 20–30 min by public or active transport 7 d/wk 2. Implement integrated ticketing systems that allow seamless transfers between different modes of transportation, including buses, trains, and bicycles	
Housing and access	Support equitable development and preservation of affordable housing	Increased physical activity through active transportation enabled by equitable housing availability proximate to daily needs and employment centers Stress reduction Access to healthy food sources	1. Strengthen prohibitions on discriminatory home loan lending practices to ensure that people of all races, ethnicities, and backgrounds have access to home ownership 2. Increase planning, zoning, and regulatory support for alternatives to single family homes and high-density apartments; near daily needs, services, healthy food, and employment, provide the so-called missing middle such as row houses and townhomes, multiplexes, cottage clusters, and tiny homes with shared green space; accessory dwellings; shared housing; and myriad evolving options	State, federal Local, state

(*Continued*)

Table 2. Continued

Issue	Principle or pathway to support heart health	Exposures affected	Examples of specific public policy solutions	Level of government
Food systems	Food systems should transition to ensuring nutrition security through equitable and stable availability, access, affordability, and use of foods and beverages that promote health and well-being.		1. Implement robust food service guidelines and procurement standards in government buildings, institutional feeding programs, and private sector food service 2. Support sustainable, climate-smart urban-regional agriculture and associated farmers markets and food carts to increase access to nutritious foods	Local, state, federal
Green infrastructure	Spatial distribution of parks can enable access to nature, leisure and active mobility, and increased tree canopy coverage to reduce heat stress	Temperature, noise and air pollution, stress	1. Education campaigns 2. Aggressive reforestation and green infrastructure in urban areas to reduce heat island effects 3. Spatial distribution of parks can enable access to nature, leisure, and active mobility, and increased tree canopy coverage to reduce heat stress 4. Public private partnerships to increase urban gardens in neighborhoods 5. Biophilic buildings with green walls and roofs and small pocket parks	Local, state
Water supply Wastewater management	Improve water quality by reducing pollution, eliminating release of chemicals and plastics to water bodies Reduce exposure to toxic metals, including lead in urban hot spots, often in underresourced communities	Water pollution	1. Automated networks for water quality and surveillance of release of chemicals and plastics 2. Moratorium on use of plastics and plastic-associated chemicals 3. Public education 4. Mandate adherence to safety thresholds in city water supplies with specific attention to lead, cadmium, nickel, and arsenic 5. Recycling of wastewater and stormwater	Local, state, federal
Construction materials, chemicals, plastics, and waste management	Use of low-carbon or “green” infrastructure, including cement, building materials lowers air pollution health effect. Promotion of circular design of products and materials for reuse, remanufacture, or recycle minimizes pollution of air, water, and soil together with GHGs		1. Incentives to promote green construction and materials 2. Ban and eliminate single-use plastics in urban environments 3. Pay to use for plastics that are recyclable 4. Specific mandates on disposal of plastics in urban environments such as restaurants, groceries, and public arcades	
Specific exposure mitigation				
Air quality	Reduce exposure to ambient air pollution for all people living in the United States and globally	Air pollution	1. Emission control: implement and enforce stringent emission standards for industries, vehicles, and power plants; regularly update these standards to reflect advancements in technology and understanding of air pollution 2. Public transportation improvement: invest in and expand public transportation infrastructure to reduce the reliance on individual vehicles; promote the use of electric and hybrid vehicles through incentives and subsidies 3. Vehicle emission controls: implement and enforce vehicle emission testing programs; introduce vehicle emission standards and promote the use of electric and hybrid vehicles 4. Industrial emissions: enforce strict regulations on industrial emissions and provide incentives for companies to adopt cleaner production technologies; implement monitoring systems to track and control emissions from industrial sources	State, federal
Noise pollution	Reduce noise exposures in urban environments	Noise pollution	1. Enact noise guidelines in urban environments that are consistent with global standards (eg, road noise <53 dB L_{den} and <45 dB L_{night}) 2. Harmonize solutions that reduce noise with other key provisioning systems such as buildings, green infrastructure, and transportation solutions that may aid in reducing ambient noise	Local, state, federal

(*Continued*)

Table 2. Continued

Issue	Principle or pathway to support heart health	Exposures affected	Examples of specific public policy solutions	Level of government
Adverse temperatures	In populations exposed to high ambient temperatures, strategies to protect populations from excess indoor heat should be developed and implemented.	Temperature	1. Education campaigns 2. Aggressive reforestation and green infrastructure in urban areas to reduce heat island effects	Local, state, federal

GHG indicates greenhouse gas.

materials into urban areas afford a generational opportunity to transform health. Two broad pathways and associated specific strategies that could enable transformation toward heart health, environmental sustainability, and equity include integrated spatial design and supply-side innovations in provisioning systems that include health, with attention to addressing disparities and partnering with communities. Although extensive new investigations are required to assess the impact and to evaluate the influence of the built urban environments on cardiovascular and metabolic health, translation of current understanding into action will necessitate active engagement of a wide range of relevant stakeholders. In this report, we provide concrete considerations and an actionable framework with which one may begin to consider the cardiometabolic health impact of risk exposures, not just as individual factors but collectively as a framework. Such an understanding is prerequisite to the attainment of equitable cardiometabolic outcomes while meeting climate goals.

ARTICLE INFORMATION

The American Heart Association makes every effort to avoid any actual or potential conflicts of interest that may arise as a result of an outside relationship or a personal, professional, or business interest of a member of the writing panel. Specifically, all members of the writing group are required to complete and submit a Disclosure Questionnaire showing all such relationships that might be perceived as real or potential conflicts of interest.

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Disclosures

Writing Group Disclosures

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CLINICAL STATEMENTS AND GUIDELINES

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This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $5000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $5000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

*Modest.

†Significant.

Reviewer Disclosures

Reviewer	Employment	Research grant	Other research support	Speakers' bureau/ honoraria	Expert witness	Ownership interest	Consultant/ advisory board	Other
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Srikanth Nadadur	NIH	None	None	None	None	None	None	None
Dorairaj Prabhakaran	Public Health Foundation of India (India)	NIH (I am the PI of the GeoHealth programme funded by Fogarty International Centre of NIH to address air pollution–related issues across the life span in India.)*	Health Care Without Harm (Health Care Without Harm supports advocacy and related research to mitigate air pollution. My wife, Poornima Prabhakaran, is a recipient of grants from HCWH.)*	None	None	None	None	None
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*Significant.

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Global Spotlights

Green cardiovascular care: a call for sustainable transformation of cardiovascular practices

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Introduction

Environmental sustainability has become an urgent global priority as the impact of climate change and environmental degradation, increasingly threatens human health and planetary well-being. The US healthcare sector contributes to an estimated 8.5% of total US greenhouse gas emissions and 27% of all global healthcare greenhouse gas emissions.[1] Given the high burden of cardiovascular disease (CVD) and the nature of diagnostics and therapeutics, cardiovascular practices, in particular, have a substantial environmental impact through high utilization of energy, medical devices, pharmaceuticals, transportation, and generation of large amounts of waste. Sustainability considerations however remain conspicuously absent in modern cardiovascular care delivery and operations. The transition to sustainable practices will however require commitment across disciplines, between stakeholders and collaboration between cardiovascular specialists, policy makers, and other healthcare stakeholders including industry.

The carbon footprint of cardiovascular practices

The current model of healthcare delivery carries a substantial carbon footprint that contributes to healthcare's climate impact, *Figure 1*. Common and large sources of emissions include energy for lighting, heating, cooling, and operating medical devices (Scope 1 and 2 emissions), transportation and food consumption of patients and staff (Scope 3 emissions), and procurement and waste from medical supplies, devices, and pharmaceuticals (Scope 3).[2] Cardiac catheterization labs, in particular, produce significant amount of single-use equipment, including catheters, gloves, drapes, gowns, and etc., in addition to high energy utilization. With more than 1 million estimated catheterization procedures in the US annually, the carbon footprint adds up. Cardiovascular operating rooms also have high energy utilization on account of ventilation, lighting, and medical devices, and anaesthetic utilization with high greenhouse warming potential contributes to significant carbon emission.[3] Devices like stents, pacemakers, and implantable cardioverter defibrillators also have environmental impacts from metal and plastic raw materials, manufacturing processes, and transportation. With increasing use of single-use disposable devices, the waste generated in cardiac catheterization labs and operating rooms has risen. Cardiac imaging can also have significant impact on the environment given on energy use, radiation, and contrast material. Beyond the care delivery, the wide array of pharmaceuticals used in cardiovascular care has a significant carbon footprint due to raw material extraction, production, packaging, and transportation.

A systems approach to building sustainable cardiovascular practices

Transitioning to sustainable models of cardiovascular care requires a major reorientation of interconnectedness between health, environment, and society (*Figure 1*). A systems thinking perspective facilitates understanding of the complex dynamics and feedback loops that contribute to sustainability and the close interdependence of multiple systems from the micro to macro (planetary) scale. Specific tools like system dynamics modelling, causal loop diagrams, and health impact assessments allow realization of synergies and avoidance of unintended consequences.[4]

Reorganization of healthcare practices will require an appreciation of the extent to which cardiovascular practices are embedded within larger networks involving payers, suppliers, social services, public health agencies, and communities. Adopting sustainability measures should therefore consider and account for how decisions propagate through the wider system. These decisions can sometimes seem overwhelming and unattainable. However, even simple actions could have impact through actions on multiple systems, the so called 'double duty' or 'triple duty' actions. For example, reducing single-use device utilization not only decreases waste and pollution but also impacts cost, healthcare

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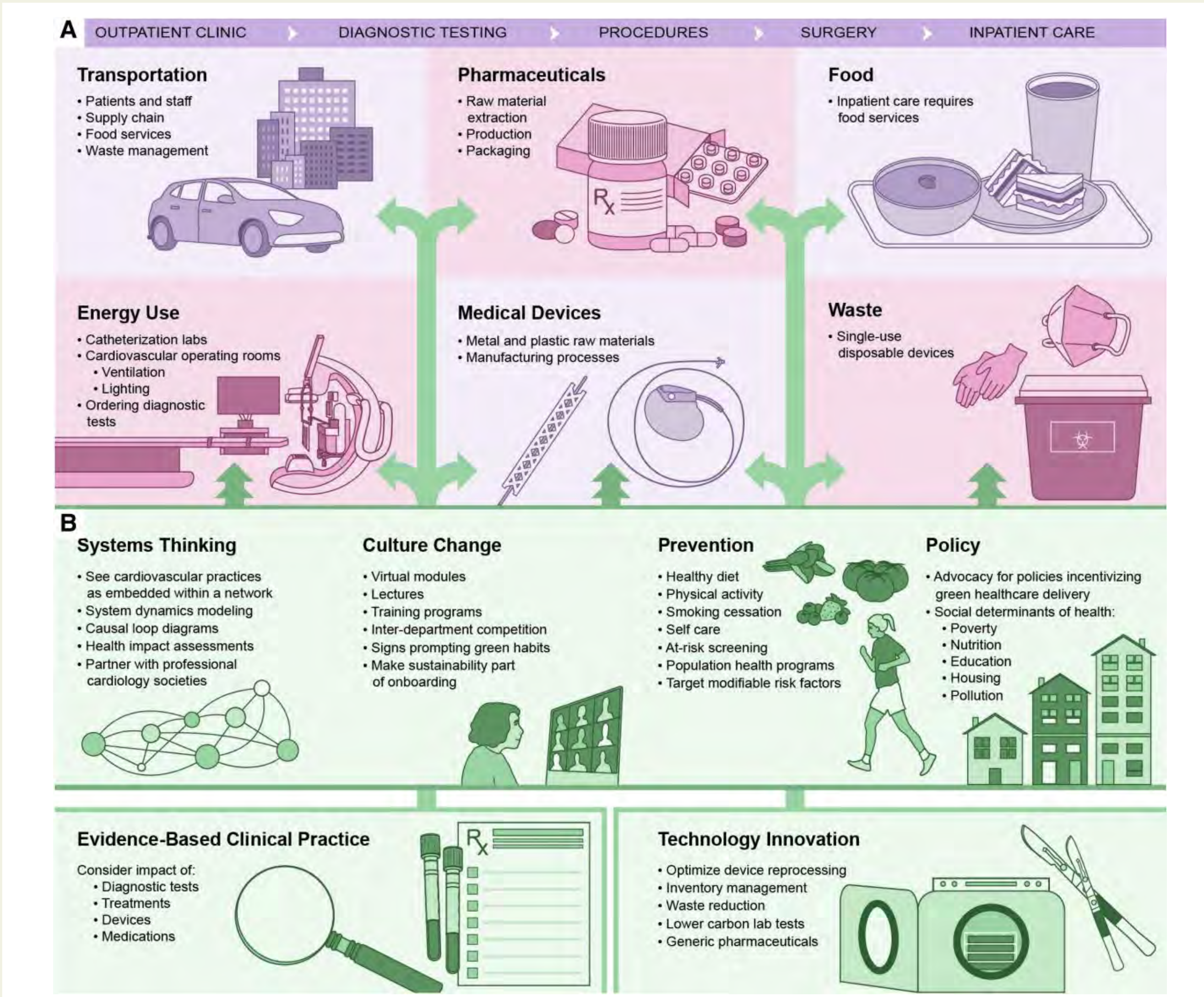

Figure 1 Pathways to a sustainable cardiovascular practice. (*A*) Key sources of emissions across the cardiovascular care continuum, including energy use, transportation, pharmaceuticals, medical devices, food, and waste. (*B*) Impactful strategies to improve sustainability at each level of the cardiovascular system

expenditure, and changes demand for these goods. Reducing food waste and single-use plastics in cafeterias in hospitals can impact carbon emissions and pollution but also help with cost. Shifting to plant-based diets in hospitals cannot only reduce carbon emissions but improve health. There is a need for immediate action to promote innovative food systems approaches that promote cardiovascular health while being sustainable.[5] Preventing cardiovascular admissions through better population health management may help reduce emission-intensive healthcare utilization and cost. Avoiding or using lower carbon lab tests and diagnostics may help improve sustainability without compromising care. Systems approaches also consider how a hospital can play a role in addressing social determinants in the community like education, housing, and community gardens to prevent chronic diseases and downstream resource utilization.

An umbrella cross-cutting organizational sustainability committee can align efforts and foster shared responsibility. The circular economy model framework referred to as the four R's: reduce, reuse, recycle, and recover, which has since evolved to nine R's (refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, and recover), is critical.[6] A shift to a circular economy model is non-trivial and necessitates substantial transformation in design, production, consumption, use, waste, and reuse practices. It will necessitate a fundamental retreat of industries focused on recycling and remanufacturing and economies of scale.

At the individual clinician level, sustainable behaviours involve understanding how our everyday workplace decisions tie into the bigger picture. Clinicians should consider the climate and environmental impacts of diagnostic tests, treatments, devices, and medications they order. They can also help patients understand how lifestyle changes prevent CVD progression and reduce healthcare utilization. For example, telemedicine may offer an opportunity to further reduce healthcare emissions.[7] Understanding of the environmental footprint of the imaging examinations can help clinicians make environmental-friendly decisions that optimize patient health and environmental health. In the catheterization laboratories, tailored utilization of devices and kits can have significant impact on the carbon footprint. Reducing the use of disposable custom packs in catheterization and using individual components that are actually needed,[8] in addition to re-using some of the supplies (e.g. gowns), can have significant reduction in carbon footprint of catheterization procedures.[9]

Building a culture of sustainability

Creating lasting impact requires instilling a culture of sustainability. Leadership commitment is crucial—hospital executives and cardiovascular practice directors must incorporate sustainability into the mission, set bold environmental goals, and dedicate resources. Appointing sustainability and Environmental, Social and Governance officers and green teams provides organizational infrastructure to develop and implement initiatives.[10]

Changing workplace culture begins with increasing awareness. Simple measures like signs prompting employees to take the stairs, shut off lights, and reduce printing foster daily green habits. Virtual modules, lectures, and training programmes for clinicians and staff build motivation and skills for participating in green initiatives. Discussing sustainability in new employee onboarding conveys these values from the start. To motivate engagement, data linking clinical decisions to emissions, waste, and environmental impacts can be powerful.

At the health system level, partnering with professional cardiology societies helps disseminate best sustainability practices and builds consensus. Advocacy for local and national policies that incentivize green healthcare delivery is key to removing barriers. Payment reforms which reward prevention and appropriate resource utilization rather than volume align with sustainability.

Embedding sustainability requires reinforcement through words, actions, and symbols that environmental responsibility is integral to cardiovascular care excellence. While challenges remain, conceptualizing sustainability as core to the clinical mission—improving both human and environmental health—creates a paradigm shift. With time, the practices and mindsets required to minimize cardiology's climate impact will become second nature. Importantly, environmental sustainability aligns with rather than compromises, healthcare's goal of delivering high-value, high-quality care.

Clinicians increasingly recognize sustainability as inherent to their mission of health promotion and view climate action as their responsibility.[2] Environmental stewardship also appeals to mission-driven younger staff and enhances recruitment. By broadcasting sustainability commitments, health systems can strengthen community trust and distinguish their brand. Healthcare sustainability ultimately requires clinicians to apply evidence-based green practices in their clinical decisions. Clinical education should integrate sustainability principles in medical school curricula and training. By taking a connected whole systems view, cardiovascular specialists can become powerful change agents in catalysing large-scale transformation.

Cardiovascular prevention as a core precept for sustainability

Reconceptualizing cardiovascular prevention as an emissions mitigation strategy recasts its impact as a pillar of sustainable cardiology practice. Prevention offers a prime example of how optimizing both human health and environmental sustainability can be mutually reinforcing. Reducing incidence and severity of CVD decreases procedural interventions, hospital admissions, pharmaceutical use, clinic visits, and medical devices and collectively lower emissions and resource consumption. Promoting plant-based planetary diets, physical activity, smoking cessation, and self-care motivates patients to take ownership of their heart health, and at the same time are sustainable. Critically, prevention extends beyond medical care to address underlying socioeconomic and environmental drivers of CVD. Tackling issues like poverty, access to nutrition, education, housing, and concomitantly with environmental pollution requires broad systems approaches synergistic with sustainability.

Challenges in sustainability

The initial costs to move to sustainable healthcare are going to be considerable, with little appetite to take on higher costs and decarbonization problems. The phasing out of fossil fuels for renewable energy to power healthcare organizations (HCOs) will help reduce anthropogenic air pollution and will have measurable, immediate impact on health, that has already been shown to outweigh upfront investment costs. It has also been argued that technology solutions and market incentives can spur innovations to shift carbon emissions substantially. In this regard, governmental regulations and requirements by organizations and societies to comply with carbon targets or risk being fined could go a long way to help HCOs transition to low-carbon health systems. Sustainability standards can no longer be optional to meet climate goals and need regulatory oversight.

Conclusion

Environmental sustainability must become an urgent priority to reduce cardiovascular medicine's climate footprint and promotion of health. While challenges exist, a new paradigm focused on the dual objectives of human and planetary health is attainable through collaboration, innovation, incentivization, and reframing sustainability as being integral to the mission of providing high-value care. The time to help pave the way to a greener, healthier future is now.

Declarations

Disclosure of Interest

All authors declare no disclosure of interest for this contribution.

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Net zero healthcare: a call for clinician action

Health professionals are well positioned to effect change by reshaping individual practice, influencing healthcare organisations, and setting clinical standards, argue **Jodi Sherman and colleagues**

Achieving net zero emissions in healthcare will be possible only with radical and immediate engagement of the clinical community. The covid-19 pandemic has served as a wake-up call for high income health systems that resources are finite and globally interdependent, vulnerable to massive surges in demands and simultaneous infrastructure disruption, and that inequities in access to care threaten health and wellbeing for everyone.

During the first months of the pandemic, the medical community united at a historic pace, rapidly sharing information, redesigning models of care, conserving and innovating resources, and moving towards a circular economy. In comparison, the task of transforming healthcare culture and practice to halve healthcare emissions by 2030 as recommended by the Intergovernmental Panel on Climate Change[1] seems entirely feasible.

Planetary healthcare

Planetary healthcare requires embracing an expanded notion of the principle "first do no harm," beyond care for individual patients to a duty to protect the Earth's natural systems on which intergenerational health and wellbeing depend.[2] This planetary health lens acknowledges crucial links between ecological change, human health, and our ability to thrive.[2]

Planetary accountability encompasses actions taken by individual health professionals within the clinical setting, collective actions of clinicians in healthcare organisations with the communities they serve, and interactions of individuals and collectives in professional societies with regulatory and oversight bodies.

For clinicians, this means recognising that healthcare consumes finite resources and produces harmful pollution, accepting that environmental stewardship is integral to our fundamental duty of care, and that we are quickly approaching a climate tipping point.

Healthcare is one of the largest polluting industries, responsible for nearly 5% of total global greenhouse gases.[3] Like all industries, healthcare must rapidly and substantially reduce its greenhouse gas emissions to avoid the most catastrophic outcomes to health and wellbeing from climate change.

Achieving net zero emissions—that is, reducing carbon output until it is in balance with natural and engineered means of absorption—necessitates optimising the efficiency and environmental performance of healthcare delivery. However, these alone are insufficient. We must also work to reduce the incidence and severity of disease to decrease the amount and intensity of care required. Furthermore, we must match supply of health services to their need, by ensuring appropriate care and avoiding unnecessary investigations and treatments. In this way, absolute emissions can be reduced while expanding access to healthcare and achieving co-benefits from mitigating harm and costs from healthcare pollution.

Health professionals are well positioned agents of change at many levels, from shaping individual clinical practices to influencing healthcare organisations and setting standards and policy. We have previously published a planetary healthcare framework setting out three strands of action: reducing emissions from healthcare services, matching supply and demand, and reducing demand for healthcare.[4] Here we provide practical suggestions to help clinicians enact that framework (table 1).

Reducing emissions from supply of health services

Reducing emissions from healthcare services encompasses all activities that consume materials and energy. Most healthcare sustainability initiatives focus on large scale facility operations, such as improving hospital energy performance and sourcing renewable electricity, which typically are not under the control of clinicians. However, clinicians influence building use through decisions on care settings—for example, whether to administer monitoring or treatment in the home, clinic, or hospital (which has the highest resource and emissions intensity).[5] Virtual care for patient-provider interactions that do not require in-person examination reduces travel and clinic emissions, obviating the need for some clinical spaces, as seen in the covid-19 pandemic.

Coordination between care providers, such as through arranging multidisciplinary consultations and services on the same day, and proximal diagnostic testing, can further minimise emissions from patient travel. Such changes often require reorganisation of processes and commitment, which can be hindered by lack of understanding of the need for coordination.

The majority of health sector emissions are embedded in the supply chain, including pharmaceuticals and medical devices.[5] Embedded emissions are dictated by materials and design, as well as production and distribution practices. Use of organisational purchasing power and regulatory reform to influence manufacturers to reduce product emissions is critical but takes time. Clinicians have an immediate role through preferential use of lower emissions supplies (such as choosing reusable rather than single use medical devices,[6] and dry powder

KEY RECOMMENDATIONS

- Clinicians must work to reduce the incidence and severity of disease to decrease the amount and intensity of care required
- Use of resources must be optimised by ensuring appropriate care and avoiding unnecessary investigations and treatments
- Coordination of care between different providers should be promoted to avoid duplication of services and reduce travel emissions and unnecessary building use
- Health professionals should encourage change through individual practice, influencing healthcare organisations, and contributing to standards and policy

Table 1 | Examples of how clinicians can act to achieve sustainable healthcare systems under a planetary health framework[4]

Intervention category	Level of action: Individual practice	Healthcare organisation	Professional/regulatory/government
Reduce emissions from supply of health services			
Green infrastructure and operations	• Paperless operations • Optimise environmental performance of office/clinic space (energy conservation, source renewable energy, safe chemicals and cleaning supplies) • Recycling	• Adhere to highest green building/retrofitting standards (eg, Leadership in Energy and Environmental Design) • Green roofs and natural lighting • Optimise efficiency of clinical infrastructure (eg, reduce medical imaging devices' standby mode time) • Food services: healthy diet options, reusable containers, waste reduction strategies (eg, people to help feed patients, just-in-time meal ordering) and waste management (biodigesters and composting) • Renewable energy sourcing •Fossil fuel divestment	•Mandatory, standardised reporting of greenhouse gas and other emissions by healthcare organisations, reductions targets and timelines, public transparency •Ambitious building construction and performance standards •Solid waste reduction policies, zero waste targets •Accelerated clean energy transition
Coordinated care delivery, integrated technology systems, and virtual care	• Offer virtual communications; select appropriate/lowest tech level • Offer multidisciplinary consultations, coordinate care with other providers to minimise patient travel • Coordinate care delivery as close to home as possible	• Multidisciplinary clinics, co-locate providers and allied health/support staff resource allocation • Information technology infrastructure and support, including integration with outside health systems to improve safety and reduce waste • Access to translation services	• Universal broadband • Financial incentives for integration of electronic health records, information sharing, and coordination • Regulation of safe adoption and use of virtual care
Circular supply chains	• Prescribe lowest carbon drug options • Select reusable or environmentally preferable materials where choices exist • Avoid excess material consumption • Adhere to evidence based infection control guidelines • Innovate and redesign greener products	• Environmentally preferable procurement and contracting policies • Maximise medical device reprocessing programmes • Institute recycling programmes • Evidence based infection prevention and control policies • Policies for rational use of single use devices	• Professional guidance and facilitation to support low carbon treatments • Policies to support keeping materials in use at highest value • Manufacturer demonstration of need for single use devices • Producer responsibility for take- back programmes (eg, packaging, electronics) • Mandate manufacturing of appropriately sized drug vials and comparably priced prefilled syringes • Revise infection control regulations and professional guidelines to incorporate public health harms from healthcare pollution • Accreditation policies that support environmental stewardship
Decarbonised transport	• Select active or low carbon transport options, encourage patients and staff to do likewise	• Provide commuter centres, carpool schemes, and subsidised public transport • Electrify vehicle fleet (owned and contracted) with renewable sources • Support structures for electric vehicles (eg, parking spaces with free charging)	• Large scale renewable energy installations/low carbon grids • Safe cycling and pedestrian infrastructure • Green active transport corridors • Bike share schemes • Designated carpool parking • Robust public transportation systems
Match supply of health services to demand			
Appropriateness of care and resource stewardship	• Shared decision making and education (articulation of harms and benefits, distinguish appropriate care from rationing, beware hidden curriculum/biases) • Avoid indication/technology creep • Avoid defensive medicine • Bayesian decision making (potential benefits should outweigh potential harms; ensure test will change management) • Maximise non-pharmacological and non-invasive treatment options • Care coordination to avoid duplication of tests and treatments • Adherence to up-to-date evidence based guidelines • Comprehensive, continuous resource conservation efforts • End-of-life acceptance and palliative care optimisation • Research and quality improvement project leadership around resource conservation and emissions reductions	• Decision making aids and policies to support individual providers, facilitate shared decision making • Technology support for care coordination • Limit conditions of use, such as through restricted ordering and automatic stop orders • Provider-level quality improvement feedback on resource use (cost and emissions) • Policies and institutional barriers to indication creep • Protocols for de-adoption of low value care and health technologies • Support structures for multidisciplinary care	• Guidelines for shared decision making • Professional guidelines that include resource stewardship and prevention of healthcare pollution • Policies to prevent indication creep • Incentives to drive de-adoption of low value care and health technologies • QI requirements around resource stewardship and emissions reductions for professional education and board recertification • Regulatory requirements and oversight of emissions reporting and reduction • Payment models that discourage low value care and link stewardship with accreditation

(Continued)

Table 1 | Continued

Intervention category	Level of action: Individual practice	Healthcare organisation	Professional/regulatory/government
Primary and community care services	• Connect patients with primary and community care, ensuring access for centralised, lifelong continuity • Shift care to home services	• Expand home care services (remote monitoring, virtual care when appropriate) • Develop technology to facilitate communication between acute, primary, and community services	•Improve remuneration for primary care providers and reduce workforce shortages • Universal healthcare
Reduce demand for health services			
Social determinants of health	• Support an anchor mission through connecting patients with community and social services (eg, food banks, churches, homeless shelters, home energy retrofit schemes, income assistance, and vocational training) • Volunteer with free, affordable clinics • Social and nature prescribing	•Adopt anchor mission mandate; establish community networks and tools that support clinicians in connecting patients with them • Provide food and transportation vouchers • Develop free, affordable clinics for the uninsured and underinsured	• Promote anchor mission model; work with local governments to establish affordable housing and public transportation • Address food deserts (eg, establish farmers' markets and new business incentives) • Universal healthcare • Climate change mitigation and resilience
Health promotion, disease prevention, and chronic disease management	• Exemplify and promote clinician wellness (eg, healthy diet, exercise, and stress reduction) • Prescribe integrative therapies (eg, yoga, meditation, chiropractic, and massage) •Social and nature prescribing •Violence screening • Provide preventive services (smoking, alcohol, and illicit drug screening, counselling and cessation aids; vaccination education and provision; reproductive health) •Person centred care, co-production/patient empowerment as active partners in care	•Offer healthy diet options • Allocate resources (funding, staff and space) for preventive services (smoking, alcohol, and illicit drug cessation; vaccinations; reproductive health) • Identification and targeting of at risk groups for major diseases • Early diagnosis and intervention in chronic/progressive disease • Secondary and tertiary prevention (such as falls prevention services) • Promote staff health and wellbeing (eg, through mental health awareness training, ethical employment practices, access to green space, encouraging active travel and healthy diets)	• Fair compensation of health professionals for health promotion and preventive services • Urban infrastructure to promote health and wellbeing (pedestrian and cycling lanes; green spaces) • Taxation to discourage unhealthy behaviours • Gun control policies •Infectious disease/zoonosis prevention and control •Clean air quality standards • Heat and air quality index alerts • Air conditioner vouchers • Professional guidance and facilitation to support low carbon care

inhalers over metered dose inhalers), and especially through reducing unnecessary consumption of supplies and treatments in their clinical practice.

Matching supply to demand of health services

Inappropriate or low value care, in which harms or costs outweigh benefits, is ubiquitous in health systems in both high and low income settings. It includes overuse and underuse of healthcare services, which often coexist in the same health system (and even for the same patient). Mismatches between supply and demand of health services occur because of health system structure and funding and behaviours of clinicians and patients that drive misuse.

Underuse of necessary services leaves patients vulnerable to avoidable disease. Overuse results in harms to patients from adverse events and exposures, financial harms to health systems and possible supply shortages, and population level disease burden from pollution generated by healthcare. Appropriate care optimises health and wellbeing by delivery of what is needed, wanted, clinically effective, affordable, equitable, and responsible in its use of resources.[7] High value care also maximises environmental performance, avoiding harm to public health.

A robust primary care system is foundational to appropriate care and provides a platform for overcoming barriers to change.[8] In high income countries, lack of access to, or inadequate primary and preventive care services results in patients interacting with more resource intensive health services such as hospital based treatment. For example, patients may present with advanced disease that would have been preventable or manageable if detected earlier.

Clinicians can mitigate unnecessary use of hospital services by facilitating access to primary and community care services. This includes identifying and targeting underserved groups, moving beyond treating the results of ethnic and economic disparities and seeking to tackle the root cause of inequities by building community wealth (the "anchor mission"). Screening patients for the social determinants of health can identify those at risk and guide health systems to influence community investments. Clinicians can also engage in innovative delivery models that allow care historically offered in the acute setting to be delivered in the community (for example, using remote physiological monitoring and mobile apps.)

In light of the many harms resulting from inappropriate delivery of health services, clinical decision making should be viewed through a stewardship lens—that is, the careful and responsible management of healthcare resources entrusted to providers. Instead, evidence indicates widespread overuse of resources such as medical supplies, medications (beyond opioids and antibiotics),[9] and laboratory and radiological investigations.[10]

Globally, a quarter of the total volume of healthcare services is low value.[7] Solutions include clinician education and empowerment, development of and adherence to evidence based standards of care that incorporate environmental harms, de-adoption[11] of low value care, shared decision making, care coordination, and continuous quality improvement, all grounded in a fundamental duty of resource stewardship and care for planetary health.

Evidence and education

Formal education should include training in planetary health and stewardship principles.[12] Continuing education is required to remain up to date on best practices, as well as indications for specific tests and interventions. The ability to critically appraise evidence, extrapolate findings to appropriate patient populations, and identify industry influence or conflicts of interest is essential to providing high value care.

By keeping their knowledge thorough and current, health professionals can protect against "technology creep"—the application of technologies or treatments to expanded indications without supporting evidence. New evidence or alternative technologies can also result in existing technologies or practices becoming inappropriate or obsolete, necessitating de-adoption strategies.[11] A core driver of resource misuse is ignorance of the evidence and failure to change practice.[13] This is compounded by ethical failures around resource stewardship and lack of appreciation of the rapid rate of environmental degradation and healthcare's contribution to it.

It is also important to understand the risks and benefits of different options, including non-pharmacological and non-invasive approaches. This knowledge can help patients to have appropriate expectations of what is knowable and treatable. Rather than striving for "zero harm," which is unattainable and results in unintended consequences, clinicians should embrace risk reduction.[14] A risk reduction approach considers implications for both the individual patient and society, including from consumption of finite resources and pollution generation.

Health professionals must apply current evidence, critically evaluating the likelihood that results of available tests will inform management decisions or that treatments will achieve desired outcomes. If early detection has no benefit, patients should be spared the inconvenience and anxiety of close screening or surveillance and the potential harm from treating false positive findings. Effective communication is essential to dispel mistaken notions that resource stewardship is synonymous with withholding care.

Shared decision making

Shared decision making involves clinicians helping patients incorporate personal values and preferences into the weighing of risks and benefits to arrive at tailored solutions that best meet their needs. This requires an appreciation of the harms of overdiagnosis and overmedicalisation. Shared decision making embraces a biopsychosocial approach to care and honours patient goals, tending to result in less inappropriate disease focused treatment (for example, chemotherapy at end of life, and stenting in stable coronary artery disease).[13] Studies of shared decision making aids have shown that 20% of elective procedures would be unwanted if patients had access to understandable, relevant clinical information.[13]

Care coordination

Inadequate communication and coordination between providers lead to duplicated and unnecessary services because of incomplete information about a patient's history and current circumstances. Seamless and adequate communication between primary care providers and specialists, and between specialty services such as in multidisciplinary cancer teams, avoids unnecessary care, improves safety, and provides a better patient experience. Barriers to this coordination can be reduced by dedicated staff and supporting technology such as shared access to electronic health records among different healthcare organisation networks and non-affiliated practices.

Institutional structures to drive high value care

Clinicians can work with their healthcare organisations to develop and implement structures that promote adherence to evidence based best practices and discourage wasteful practices. Restrictions on antibiotic and opioid ordering,[15] automatic stop dates on laboratory investigations, and alerts for high fresh gas flow during anaesthesia embed stewardship into electronic health records.

Institutional policies—for example, those that recommend against routine prophylaxis for stress ulcers (which data show is harmful[16]) or restrict access to desflurane (because of its disproportionate climate impact[17]), hasten the uptake of knowledge of harms and facilitate de-adoption of low value care. Specialist teams can standardise aspects of inpatient care and ensure up-to-date best practice through electronic decision support and benchmarking tools.

Developing clinical practice guidelines through professional societies lessens the responsibility on individual clinicians and confers a degree of medicolegal protection. Similarly, hospital policies and procedures can diffuse decision making responsibility, removing pressure that drives clinicians to practise defensive medicine or relieving ethical dilemmas around appropriate allocation of limited resources and end-of-life care, as happened in the covid-19 pandemic.[18]

Continuous quality improvement

Environmental performance should be integrated into the core definition of quality care, with best practices established for clinicians and health systems and reinforced through regulatory and oversight processes that overcome obstacles to change. Investigations of appropriateness of care and resource consumption lend themselves to quality improvement initiatives, which can be designed, initiated, and carried out by individual clinicians within their professional settings. Electronic health records can provide feedback to clinicians on resource use, costs, and emissions, to gauge performance and drive quality improvement.[19]

Reducing demand for health services

Reducing demand for health services requires tackling drivers of poor health. In the United States, over 50% of healthcare services are devoted to the 5% of the population with advanced chronic disease.[20] Most advanced disease develops in people who had risk factors or early stages of illness that were preventable or reversible, often through behavioural and lifestyle approaches alone.[21] Furthermore, healthcare services contribute to only 20% of health and wellbeing, with the remainder being the result of broader social, economic, ecological, and political factors.[22] However, current healthcare strategies routinely neglect social determinants of health, missing opportunities to reduce the burden, expense, and environmental effect of chronic disease. An integrative healthcare framework offers a potential solution.[23]

Integrative healthcare is the delivery of non-pharmacological and lifestyle approaches to disease prevention and treatment in coordination with conventional treatments of chronic disease.[24] Smoking cessation, reducing use of drugs (including alcohol), and better dietary habits, activity levels, and stress management can prevent or mitigate many chronic diseases.[7] Evidence based approaches such as yoga, acupuncture, massage, and mind-body practices are particularly useful for pain reduction and more appropriate than medications (especially opioids) for chronic pain.[25] As part of primary care, these approaches offer opportunities to intervene upstream in health promotion and disease prevention.[23] While these behavioural and social determinants are not the sole responsibility of healthcare services, helping patients better engage and manage them could go a long way towards reducing the need for more expensive and environmentally damaging interventions later.

Prescribing nature based interventions and activities such as local walking groups, community gardening, and food growing projects can help meet health needs. Benefits of green time are most researched in mental health, with protected areas worldwide estimated to be worth the equivalent of $6tn (£4tn; €5tn) annually in mental health services.[26] Recommending patients engage socially in local community services can help tackle some of the social determinants of health such as food insecurity and social isolation.

Closing the information and practice gap

Environmental engineering tools and methods to quantify carbon and other environmental emissions are well established, and life cycle assessment is the gold standard in healthcare sustainability research.[27] Although the emissions and public health damages from low value care are not yet known, it stands to reason that reducing unnecessary care would reduce emissions and costs, provided that the emissions intensity of required care is simultaneously reduced.

The process of mobilising the clinical community around planetary healthcare requires a concomitant investment in knowledge generation to identify environmentally preferable practices, establish evidence around high value care, and guide public policy for optimal population health. Clinicians should take the lead in advancing this research agenda, while healthcare institutions, universities, and funding bodies must support the work by prioritising planetary health mandates and providing appropriate resources.

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U.S. Health Care Workers Want Their Employers to Address Climate Change

Daniella Meza-Diaz, surgical recovery coordinator in the operating room at OneLegacy on June 29, 2023, in Azusa, Calif. About four in five clinicians surveyed believe it's important for their hospital to address climate change and that doing so is aligned with their organization's mission. Photo: Francine Orr/Los Angeles Times via Getty Images

Toplines

- Clinicians want hospitals and health systems to help address climate change and minimize their impact on the environment
- Health care organizations that are taking meaningful steps to reduce carbon emissions and reduce their environmental footprint may have an easier time retaining and recruiting clinical staff

Authors
Arnav Shah, Lovisa Gustafsson

Introduction

Within the United States, the health care sector is responsible for 8.5 percent of greenhouse gas emissions, largely from hospital care and from physician and clinical services.[1] While a growing number of U.S. health care delivery organizations pledged to halve their emissions by 2030 and achieve net zero emissions by 2050, progress has been mixed. Many health systems have not made this pledge or taken meaningful steps toward decarbonization.[2]

Effective sustainability and decarbonization efforts in health care require organizationwide buy-in to new innovations, policies, and procedures targeted at reducing waste and water consumption, adopting green building features, protecting facilities from extreme weather damage, converting to renewable energy, and other activities to advance a more sustainable health system.[3] And buy-in from frontline health care workers — nurses, physicians assistants, nurse practitioners, primary care physicians, and specialists — is especially critical.

In this brief, we present findings from a national survey of 1,001 U.S. clinicians about their views of what health systems can do to address climate change. All those surveyed worked at a hospital or at a health system comprising more than one hospital; some had leadership responsibilities within their organization. (See "How We Conducted This Survey" for further details.) It is our hope that the findings could help motivate health care organizations to consider ways to decarbonize and reduce their environmental impact.

Survey Highlights

- About four in five clinicians surveyed believe that it's important for their hospital to address climate change and that doing so is aligned with their organization's mission.
- Three in four surveyed clinicians feel it's important that they themselves work to reduce their environmental impact, both at work and at home.
- Respondents working in leadership positions reported that most hospitals are increasingly undertaking climate mitigation initiatives, such as reducing energy consumption (69%) and waste (76%) or setting emissions targets (35%).
- About six in 10 clinicians indicated a prospective employer's policies and actions on climate change would impact their decision to apply for a job.

Discussion

Addressing climate change is important to health care workers. Our survey's findings suggest clinicians overwhelmingly want their employers to be working to address climate change. A majority of respondents said it was important to them that their organization play a role in minimizing its impact on the environment, as well as important that they personally address climate change at work and at home.

Climate change mitigation activities also have an impact on whether hospitals or health systems are seen as an attractive place to work. Hospitals actively engaged in addressing climate change and minimizing their environmental impact may have an easier time retaining and recruiting clinical staff. A majority of respondents said the extent to which an organization was trying to reduce its environmental impact would play a role in their decision to remain at their current job or seek work at another organization.

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WORKSHOP

Principles & Priorities for Environmentally Sustainable Digital Health

UNIVERSITY OF TORONTO
Collaborative Centre for Climate, Health & Sustainable Care

TRANSFORM HF

TUESDAY, APRIL 23 – WEDNESDAY, APRIL 24
TORONTO, CANADA

Tonight’s Agenda

1. Land Acknowledgement – Heather and Fiona

2. Welcoming Remarks – Heather and Fiona

3. Introductions – Anne to moderate

3 things in 30 seconds:

1. Your name and affiliation
2. The perspective you are bringing to our dialogue
3. An area or problem you are keen to explore within our theme of sustainable digital health

4. Setting the Stage - Geoff

- Developing insights at the intersection of big ideas
  - Climate change and sustainable care
  - Cardiac care and digital innovation
- Listening to thought leaders
  - Understanding the issues
  - Frameworks for action
- Working together
  - Listening to new ideas
  - Finding common ground
  - Develop a strategy to engage others

COP28 UAE

COP28 UAE DECLARATION ON CLIMATE AND HEALTH

COP28 Declaration on Climate and Health Common Objectives

Promoting a comprehensive response to address the impacts of climate change on health, including, for example, mental health and psychosocial wellbeing, loss of traditional medicinal knowledge, loss of livelihoods and culture, and climate-induced displacement and migration.

Combating inequalities within and among countries, and pursuing policies that work towards accelerating achievement of the Sustainable Development Goals, including SDG3; reduce poverty and hunger; improve health and livelihoods; strengthen social protection systems, food security and improved nutrition, access to clean sources of energy, safe drinking water, and sanitation and hygiene for all; and work to achieve universal health coverage.

Promoting steps to curb emissions and reduce waste in the health sector, such as by assessing the greenhouse gas emissions of health systems, and developing action plans, nationally determined decarbonization targets, and procurement standards for national health systems, including supply chains.

Strengthening trans- and inter-disciplinary research, cross-sectoral collaboration, sharing of best practices, and monitoring of progress at the climate-health nexus, including through initiatives such as the Alliance for Transformative Action on Climate and Health (ATACH).

COP28 Declaration on Climate and Health Common Objectives

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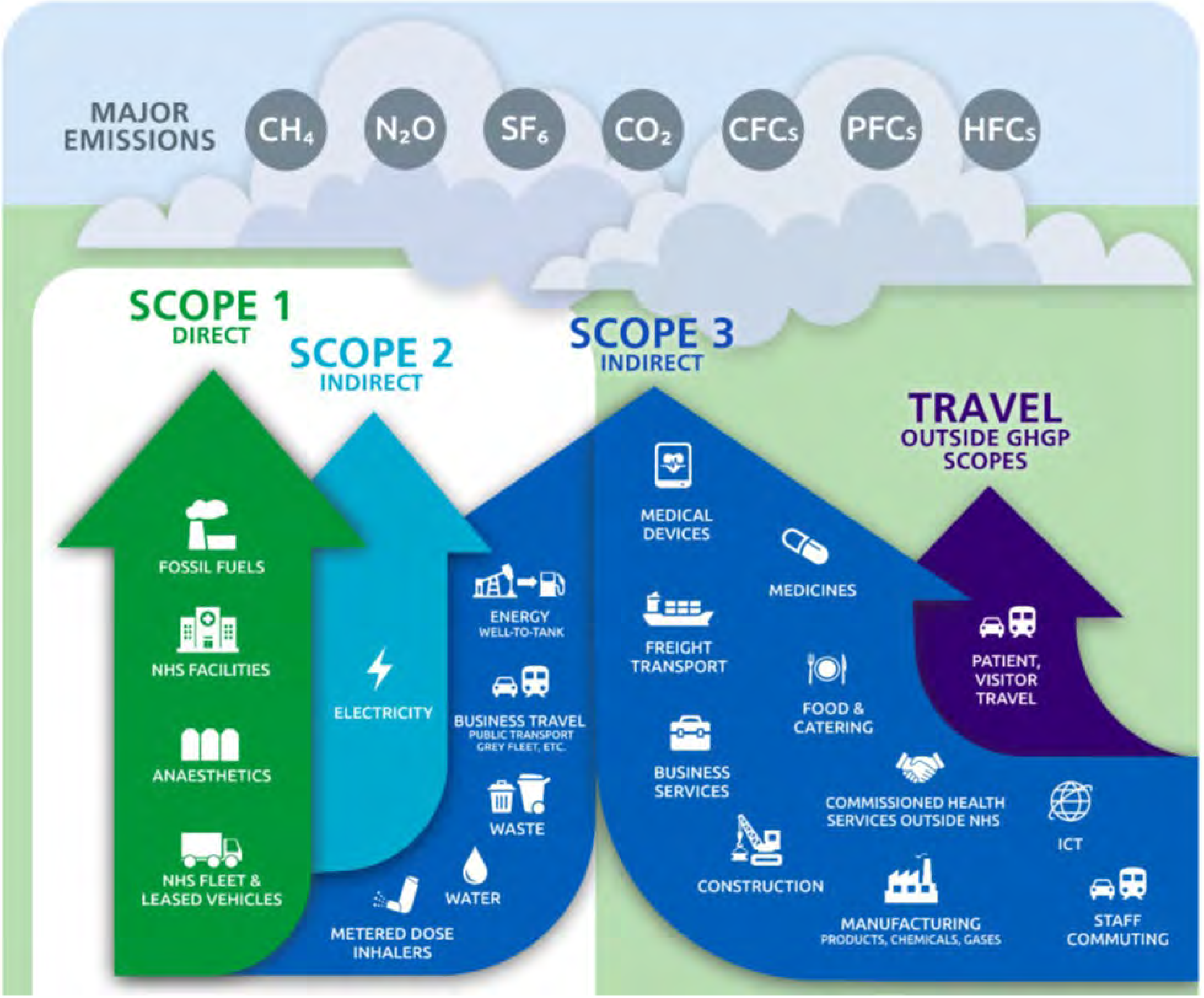

MAJOR EMISSIONS
CH4
N2O
SF6
CO2
CFCs
PFCs
HFCs
SCOPE 1
DIRECT
SCOPE 2
INDIRECT
SCOPE 3
INDIRECT
TRAVEL
OUTSIDE GHGP SCOPES
FOSSIL FUELS
NHS FACILITIES
ANAESTHETICS
NHS FLEET & LEASED VEHICLES
ELECTRICITY
ENERGY
WELL-TO-TANK
BUSINESS TRAVEL
PUBLIC TRANSPORT
GREY FLEET, ETC.
WASTE
WATER
METERED DOSE INHALERS
MEDICAL DEVICES
MEDICINES
FREIGHT TRANSPORT
FOOD & CATERING
BUSINESS SERVICES
COMMISSIONED HEALTH SERVICES OUTSIDE NHS
CONSTRUCTION
MANUFACTURING
PRODUCTS, CHEMICALS, GASES
ICT
STAFF COMMUTING
PATIENT, VISITOR TRAVEL

AMERICAN COLLEGE of CARDIOLOGY

Cover Story | Cardiology's Digital Transformation: Telehealth, Remote Monitoring and AI

Technology-Enabled Collaboration Across the Entire Health Care Ecosystem

Nov 17, 2021

Cardiology Magazine

Cardiology digital playbook

How to use digital ways of working to improve outcomes for patients

This resource provides support to clinical teams and organisations that are looking for digital tools that support the delivery of patient pathways. We concentrate on cardiology pathways and how to deliver monitoring and support to patients. We welcome feedback on the playbooks, including ideas for further case studies. To get in touch, please email digital.playbooks@nhs.net

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Net zero healthcare: a call for clinician action

Health professionals are well positioned to effect change by reshaping individual practice, influencing healthcare organisations, and setting clinical standards, argue **Jodi Sherman and colleagues**

Achieving net zero emissions in healthcare will be possible only with radical and immediate engagement of the clinical community. The covid-19 pandemic has served as a wake-up call for high income health systems that resources are finite and globally interdependent, vulnerable to massive surges in demands and simultaneous infrastructure disruption, and that inequities in access to care threaten health and wellbeing for everyone.

During the first months of the pandemic, health and wellbeing depend.[2] This planetary health lens acknowledges crucial links between ecological change, human health, and our ability to thrive.[2]

Planetary accountability encompasses actions taken by individual health professionals within the clinical setting, collective actions of clinicians in healthcare organisations with the communities they serve, and interactions of individuals and collectives in professional societies with regulatory and oversight bodies.

For clinicians, this means recognising strands of action: reducing emissions from healthcare services, matching supply and demand, and reducing demand for healthcare.[4] Here we provide practical suggestions to help clinicians enact that framework (table 1).

Reducing emissions from supply of health services

Reducing emissions from healthcare services encompasses all activities that consume materials and energy. Most healthcare sustainability initiatives focus

Perspective

i-CLIMATE: a "clinical climate informatics" action framework to reduce environmental pollution from healthcare

Dean F. Sittig[1] **Jodi D. Sherman**[2,3] **Matthew J. Eckelman**[4], **Andrew Draper**[5], **and Hardeep Singh**[6]

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Improving Health Care Quality →

ISSUE BRIEFS / JANUARY 24, 2024

U.S. Health Care Workers Want Their Employers to Address Climate Change

Toplines

Clinicians want hospitals and health systems to help address climate change and minimize their impact on the environment

Health care organizations that are taking meaningful steps to reduce carbon emissions and reduce their environmental footprint may have an easier time retaining and recruiting clinical staff

Authors

Arnav Shah, Lovisa Gustafsson

Some common threads

Supply/provide digital services in the most sustainable fashion possible

Match the supply/provision of digital services to the need for those services

Use digital innovation to reduce demand/need

Create the right structures and engage healthcare professionals

Supply/provide digital services in the most sustainable fashion possible

Purchase sustainably

Power sustainably

Monitor and measure

Match the supply/provision of digital services to the need for those services

Replace existing services with services that are more sustainable

Reduce waste and duplication

Focus on impacts on health

Use digital innovation to reduce demand/need for care

Primary prevention of cardiac disease through risk factor modification

Secondary prevention of cardiac disease through screening and early treatment

Make the tertiary care aspect of cardiac care smaller

Create the right structures and engage healthcare professionals

Institutions and professional associations that incorporate and apply principles of sustainable healthcare

Healthcare professionals who incorporate and apply principles of sustainable healthcare

Pop Quiz

Which digital innovation in cardiology do you think could have the greatest **positive** impact on healthcare sustainability

Electronic health records and imaging

Virtual care and remote monitoring

AI to support precision medicine

Pop Quiz

Which digital innovation in cardiology do you think could have the greatest **negative** impact on healthcare sustainability

Electronic health records and imaging

Virtual care and remote monitoring

AI to support precision medicine

Key principles for our work together

Listen to new ideas and see from a different perspective

Find the common ground

Develop a message that can engage others

Thank you!

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TRANSFORM HF

Promises and perils of digital transformation

Dr Gabrielle Samuel

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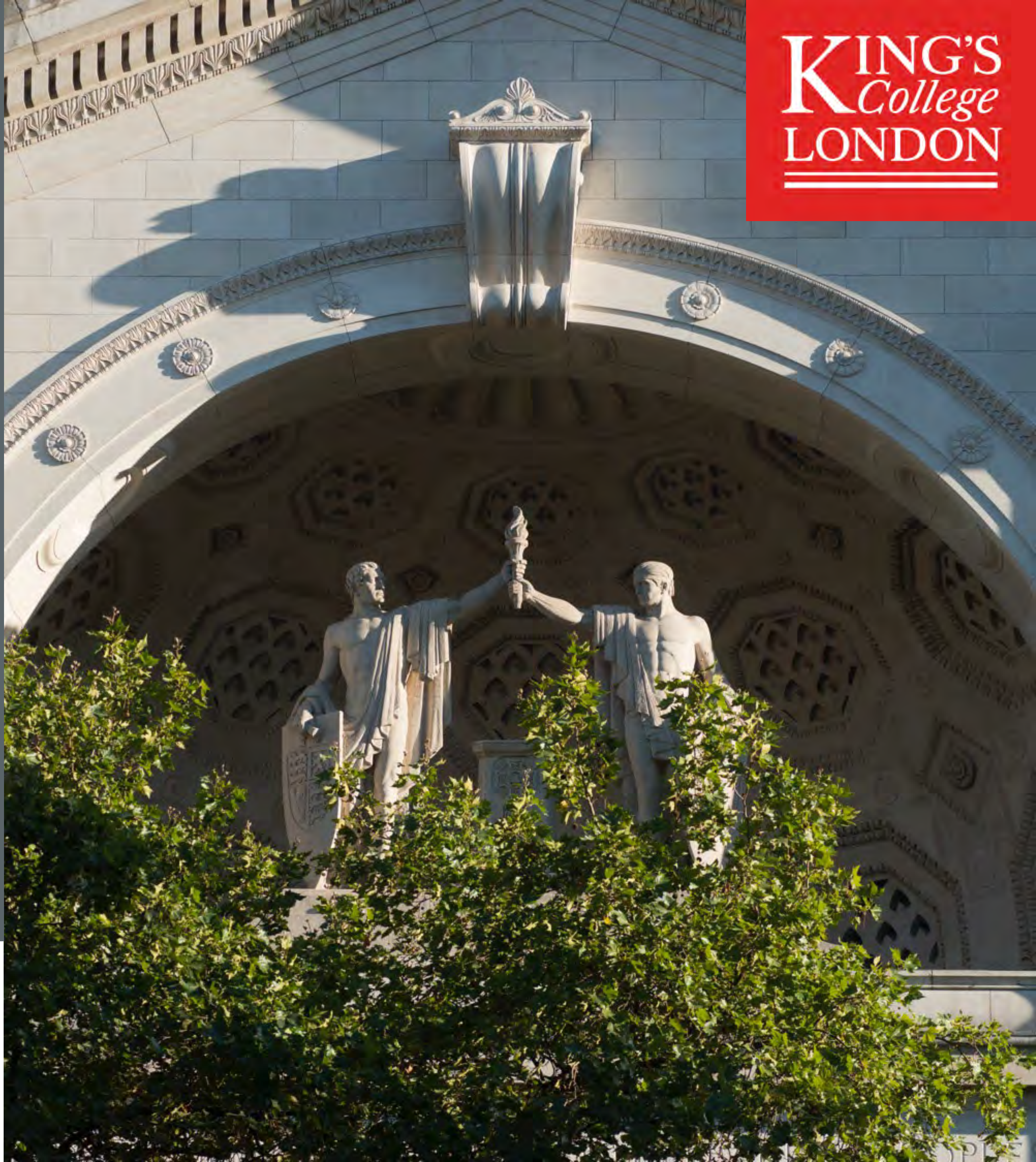
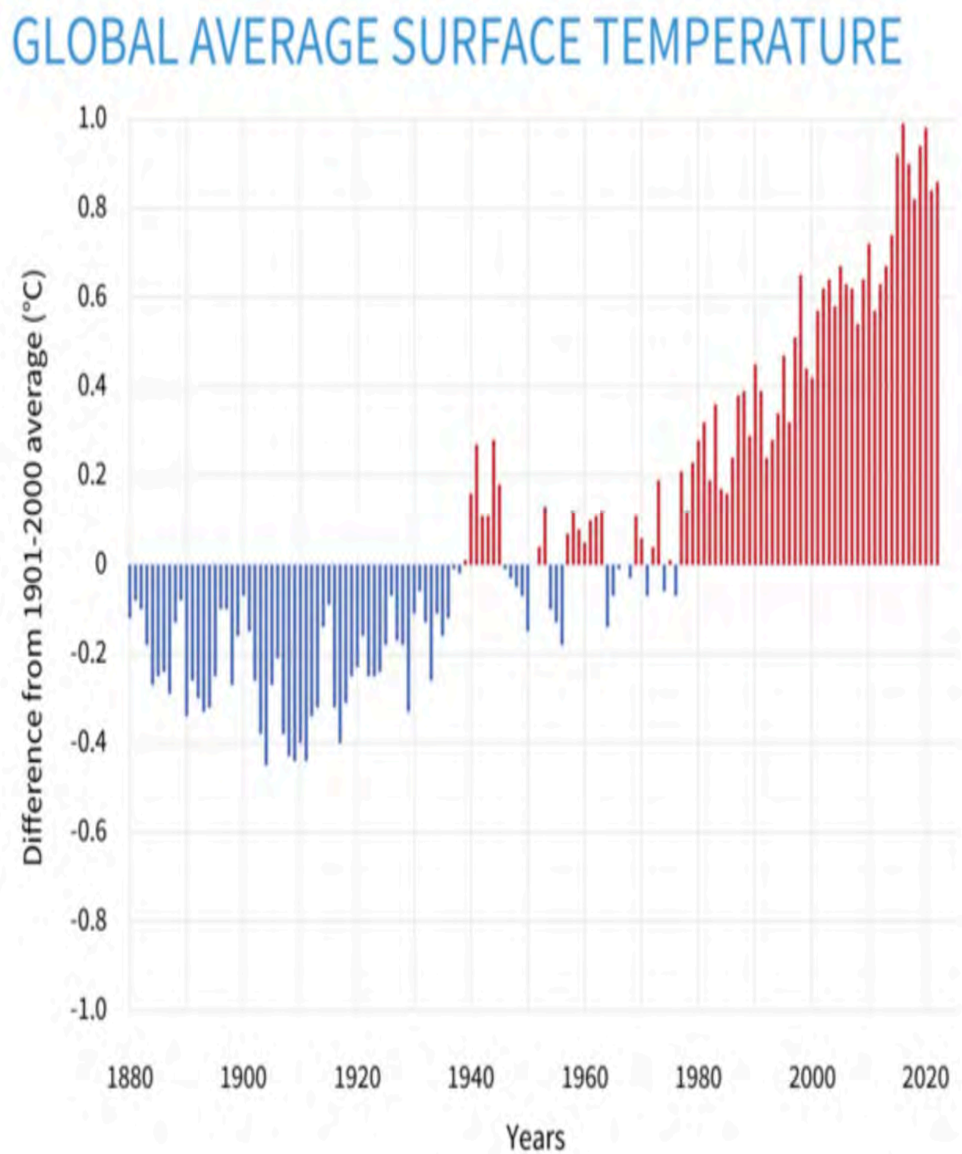
wellcome



Premise of talk

- There’s a moral imperative to consider environmental sustainability in health care
- Digital technologies give us one way to do this
- But they are not a technological solution…
- A more systems approach offers a way to think about the issues that need addressing

Healthcare ~ 5% global GHG emissions [Canada: 4.6%]



Yearly surface temperature compared to the 20th-century average from 1880–2022. Blue bars indicate cooler-than-average years; red bars show warmer-than-average years. NOAA Climate.gov graph, based on data from the National Centers for Environmental Information.

Direct physical effects of climate change…

- + Drought and wildfires
- + Availability of fresh water
- + Floods
- + Sea-level rise and coastal areas
- + Biodiversity
- + Soils
- + Inland water
- + Marine environment

‘Hundreds were saved’: Heavy rains cause record death toll in southern Brazil

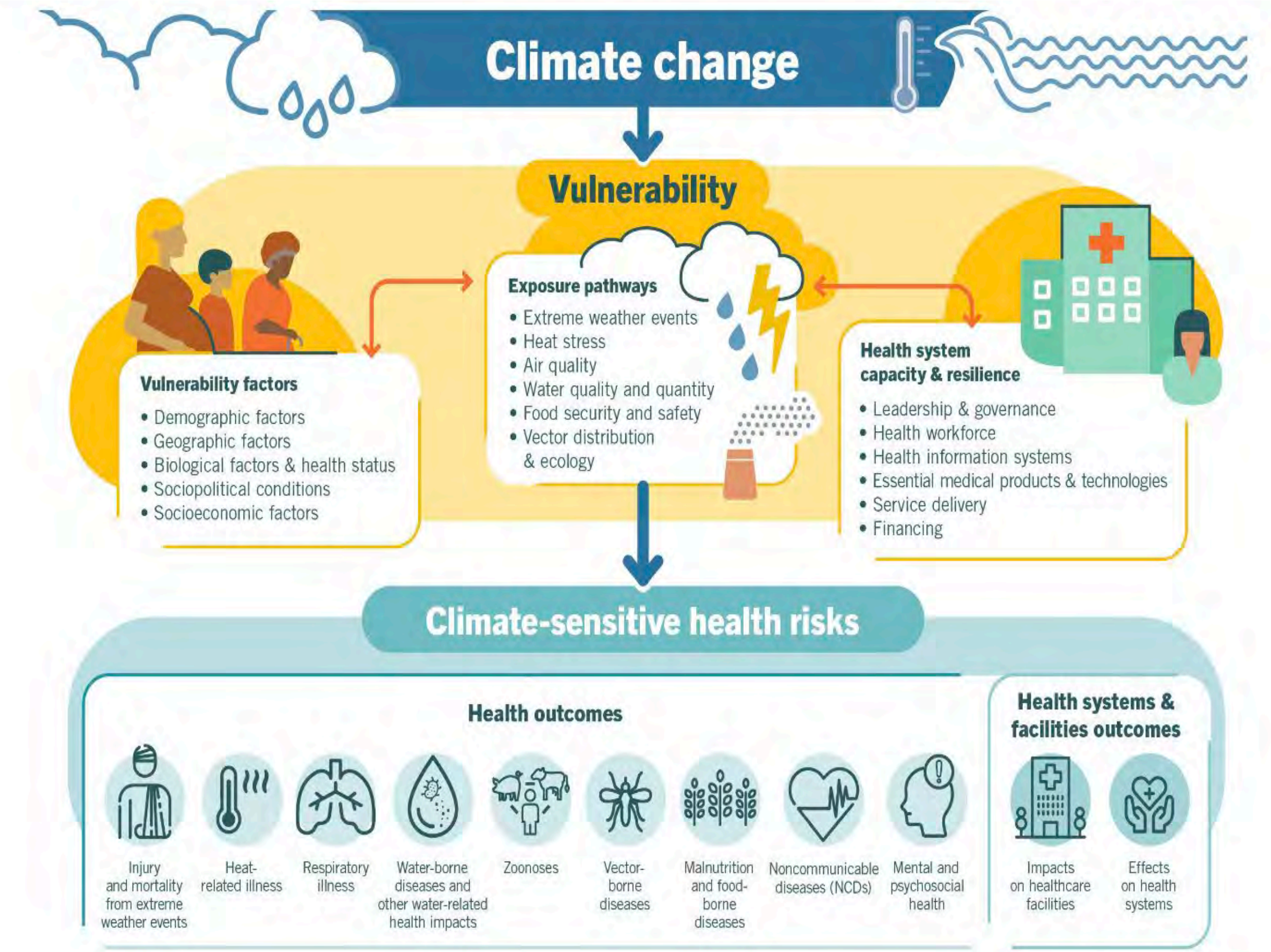
Asia Pacific

Strong winds fan bushfires as Australia battles spring heatwave

By Renju Jose

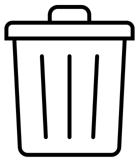
Indirect social/political effects of climate change…

Social/political/environmental factors: determinants of health
"**the climate crisis is a health crisis" [COP28]**



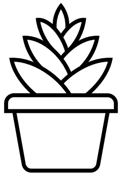
https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health

Other environmental impacts: healthcare



- **Waste:** much is single-use plastic items (syringes, blood bags, tubing). COVID-19 pandemic: 8 million tonnes of pandemic-associated plastic waste, primarily from hospitals (Peng, Wu et al. 2021). Much ends up in the sea.

- **Water:** the total water footprint of the UK NHS seeing a 21% reduction from 2010 levels - the same water volume as 243,000 Olympic swimming pools (NHS England 2018).



- **Biodiversity:** including direct effects (e.g., chemical pollution from pharmaceutical residue in water,) and indirect effects (e.g., through shipping's impact on foreign species transfer or whale strikes).

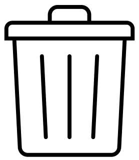
Estimated: 1.15 to 2.41 million tonnes of plastic enter the ocean each year from rivers.

Animals Are Migrating to the Great Pacific Garbage Patch

The oceanic soup of plastic fragments is becoming a new kind of ecosystem.

By Sarah Zhang

Other environmental impacts: healthcare



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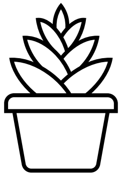

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Moral imperative to consider these issues (either via anthropocentric or eco-centric narratives)

- Adverse environmental and health impacts are particularly problematic when there appears to be an internal contradiction between the goal of improving health conditions and the environmental and health risks due to their environmental impact

- As such , the health sector has a special interest in addressing its adverse environmental and health impacts, not only as a matter of international priority, but also as a commitment to health

Many different ethical justifications for change

1. Utilitarian: failing to consider the burdens associated with healthcare creates imbalances in any utilitarian decision-making approach because it means ignoring key links in the consequentialist pathway that are associated with harms that come during the manufacturing, use and disposal of healthcare products. Pierce and Jameton (2004) argue that when these burdens are added, ‘everyday decisions unquestioned by ethicists and regarded as rational and even praiseworthy may be seen as questionable and possibly maleficent’ (p119).

2. Justice: is a key underlying principle of many modern day societies. In a globalised world, to be just means ensuring the fair and equitable distribution of benefits and burdens not only within national boundaries but for all those who are subject to a given governance structure. Understandings of justice developed in recent decades argue that all individuals and communities affected by a particular process or product wherever they are in the world, and whatever aspect they are affected by, have moral standing and should be the subjects of justice considerations (e.g. Marion Young / Fraser’s, ‘all subjected principle’)

Original research

Reimagining research ethics to include environmental sustainability: a principled approach, including a case study of data-driven health research

OPEN ACCESS

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ABSTRACT

In this paper we argue the need to reimagine research ethics frameworks to include notions of environmental sustainability. While there have long been calls for health*care* ethics frameworks and decision-making to include aspects of sustainability, less attention has focused on how *research* ethics frameworks could address this. To do this, we first describe the traditional approach to research ethics, which often relies on individualised notions of risk. We argue that we need to broaden this notion of individual risk to consider issues associated with environmental sustainability. This is because research is associated with carbon emissions and other environmental impacts, both of which cause climate change health hazards. We introduce how bioethics frameworks have considered notions of environmental sustainability and draw on these to help develop a framework suitable for researchers. We provide a case study of data-driven health research to apply our framework.

INTRODUCTION

Dominant research ethics paradigms often revolve around ethics principles that are concerned with the protection, rights, safety and welfare of *individual* research participants. These paradigms can be traced back to a number of historical ethics

While individualised risk has long been a focus of research ethics frameworks, strong criticism exists around it. In an interconnected world it is difficult to argue that the impacts of individual research treatment would not affect others, particularly in the closer communities of friend and family groups. Carol Gilligan's work on care ethics[4] and the notion of relational autonomy both point to the networks that impact ethical decision-making within healthcare. Furthermore, concerns have long been raised about the appropriateness of placing individual risk ahead of *communitarianism*, especially in research areas that are less concerned with individual health, such as global health research. Public health scholars have long pointed to the moral status of the community in research ethics considerations,[5-8] whereby community harms are more than the sum of individual values and interests and relate to questions associated with whether communities will be beneficiaries of the research, or even whether they share the same goals as the researchers.[9-11] Multiple authors have pointed to the abusive practices and problematic studies conducted with tribes, indigenous populations, and minoritised and marginalised communities worldwide over the past decades, which have failed to consider community harms associated with violating widespread trust or taking

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Opinion

VIEWPOINT

CLIMATE CHANGE AND HEALTH

Clinical Research Risks, Climate Change, and Human Health

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Division of Clinical Public Health, Dalla Lana School of Public Health, University of Toronto, Toronto, Ontario, Canada; and Program for Ethics and Care Ecologies (PEaCE), Hamilton Health Sciences, Toronto, Ontario, Canada.

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For clinical research to be deemed ethically acceptable, it is necessary that a study have a favorable benefit-risk ratio.[1] This requirement is met when risks and harms are minimized, potential benefits are maximized, and the potential benefits outweigh the potential risks.[1]

In evaluating the risks of clinical research, institutional review boards (IRBs) and ethics committees concentrate primarily on those risks related to the health of participants. However, when calculating the potential benefits, they expand their purview to include the health of nonparticipants, including those from both present-day as well as future generations.[1] The focus on risks to participants is understandable, given that history's most egregious research-related harms have directly affected research participants. Nonetheless, it stands to reason that if present-day and future-generation nonparticipants matter when calculating the potential health benefits of clinical research, then present-day and future-generation nonparticipants should also matter when calculating the health risks and harms associated with clinical research. Not to do so gives rise to a risk-benefit calculation—and clinical research conduct—that is unbalanced, misguided, and does not properly respect the rights, safety, and welfare of nonparticipants and future generations.

> Health risks and harms associated with clinical research include, among other issues, those associated with anthropogenic climate change.

Health risks and harms associated with clinical research include, among other issues, those associated with anthropogenic climate change. (Clinical research is associated with a range of environmental and other harms, such as those related to extraction of resources, exploitation of labor, and the production of [toxic] waste.

registered on ClinicalTrials.gov—just a subset of clinical trials globally—being estimated at 27.5 million tons, which is just less than one-third of the total annual carbon emissions of Bangladesh, a country of 163 million people.[4]

Given these current and impending harms, the scientific community, policymakers, IRBs, and ethics committees can no longer claim ignorance of the fact that human activity—including clinical research—negatively affects both participants and nonparticipants alike, and it is untenable to omit these effects when calculating the potential benefits and risks of conducting clinical research. Of course, simply calculating the carbon footprint associated with clinical trials is not enough: to be ethically acceptable, the carbon footprint of clinical trials—and the related harms of clinical research—must be minimized to maximize the net benefits of research. While there is a range of possible approaches to achieve this behavior change within the research community, as stewards of ethical research, IRBs and ethics committees have an important role to ensure the benefit-risk ratio is upheld within research practice. To fulfill this role, IRBs and ethics committees must ensure that research studies (1) calculate and minimize the carbon dioxide equivalent (CO_2e) emissions associated with a clinical study, (2) disclose the associated carbon footprint of their research, and (3) have a feasible mitigation and carbon offset plan for those CO_2e emissions that cannot be reduced to ensure that their study achieves net-zero CO_2e emissions. IRBs and ethics committees may then make research ethics approval contingent, in part, on meeting these 3 conditions. It is important to note that many carbon offset plans do little to address the effects of carbon use. As such, they should be a last resort, and the companies chosen to offset CO_2e emissions must be effective at doing so.

Because IRBs and ethics committees do not presently calculate the potential benefits and risks of re-

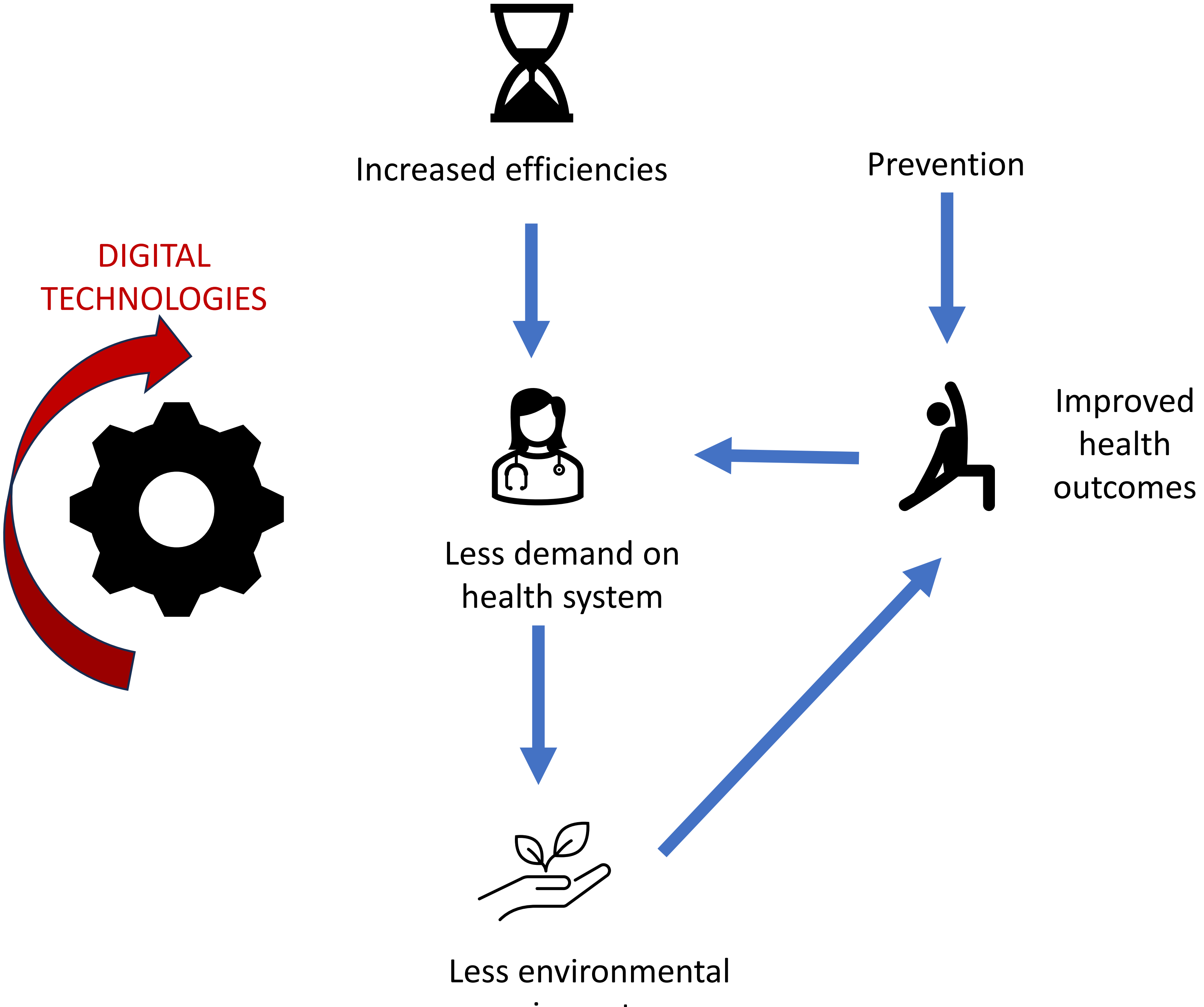
3. For planetary health, humans and the environment flourish together and a planetary health ethic requires that all aspects of environmental and human health are respected during decision-making practices.

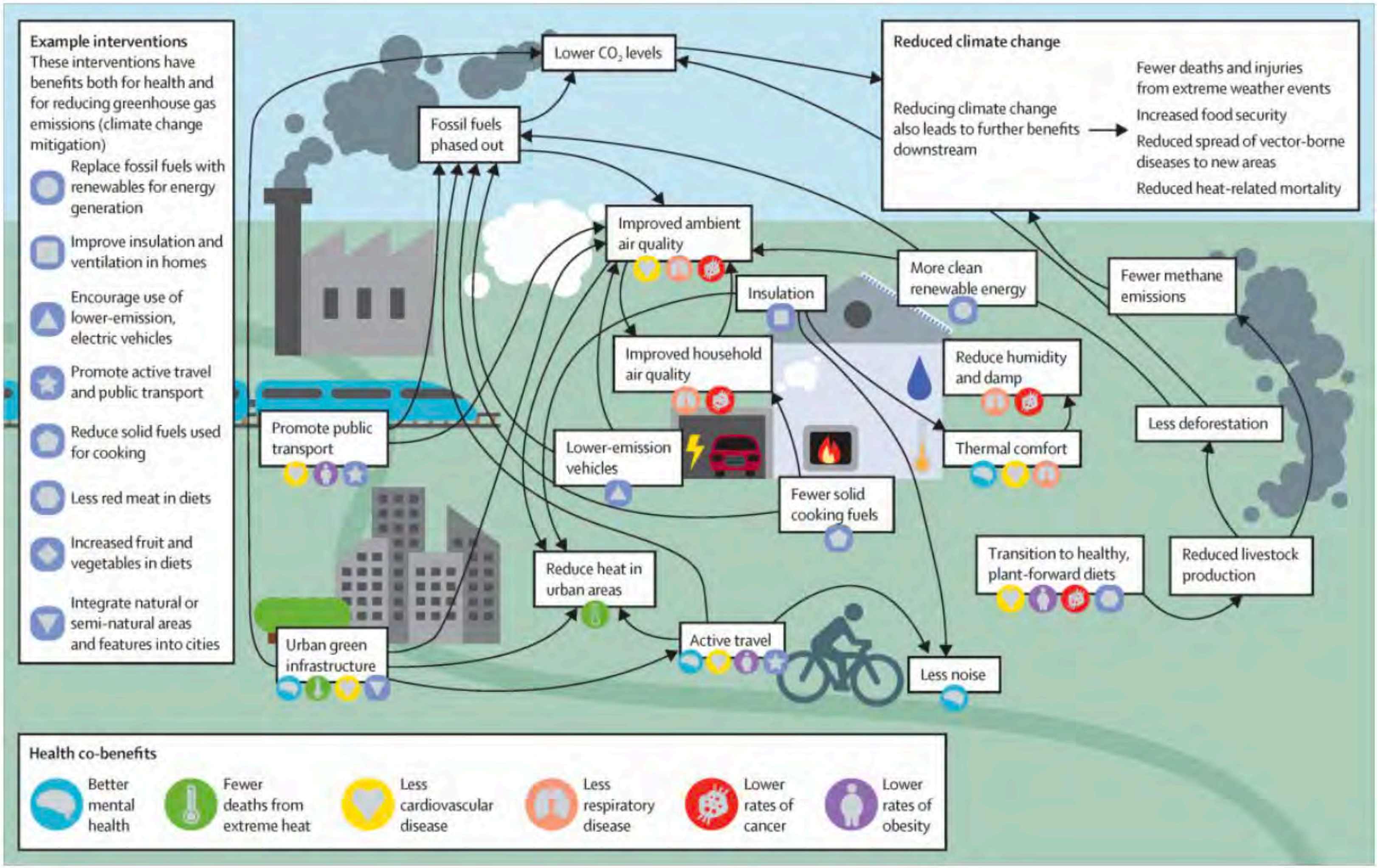
4. Bridget Pratt / Peter West-Oram and Alena Buyx:

Solidaristic global health infrastructure should respond to health needs of distant others and seek to alleviate common global threats to health such as climate change and pandemic diseases

Digital transformation as a way to address healthcare's environmental impacts?

How digital tools might/can contribute to decarbonising healthcare	Examples
Improving the operational efficiency of existing healthcare infrastructure	• Use sensors for turning off lights and controlling room temperatures • Forecasting healthcare facility energy and water consumption to detect and address anomalies • Forecasting resource use so only the necessary supplies are purchased
Providing applications and/or services that have lower environmental impacts than non-digital ones	• Replacing paper records with electronic medical records • Replacing in-person visits with virtual visits
Keeping the population healthy and reducing the demand for healthcare	• Using large databases and advanced AI algorithms to support improved clinical decision making and patient interaction


Increased efficiencies
Prevention
DIGITAL
TECHNOLOGIES
Improved
health
outcomes
Less demand on
health system
Less environmental
impacts



Pathways to a healthy net-zero future: report of the Lancet Pathfinder Commission

Importance of digital technologies e.g. cardiology

NHS

GIRFT

GETTING IT RIGHT FIRST TIME

Cardiology networks will deliver better access to care, says GIRFT national report

Clinically-led reviews of specialties to examine how things are currently being done and how they could be improved

The GIRFT report views *'digital tools as a way to improve communication between patients and clinicians and to help forestall deterioration that might lead to hospital admission, which could have been avoided. The report recommends using digital tools to design and improve patient-centred cardiology pathways'.*

CARDIOVASCULAR

Mayo researchers use AI to detect weak heart pump via patients' Apple Watch ECGs

Terri Malloy

May 2, 2022

News | Artificial Intelligence | October 04, 2023

American College of Cardiology and Serv Medical Announce Collaboration on Digital Health Care Innovation

The American College of Cardiology (ACC) recently announced that it has started a strategic innovation collaboration with Serv Medical, a Singapore-based healthcare big data and artificial intelligence (AI) company, toward the goal of revolutionizing cardiovascular care through digital therapeutics and fostering medical excellence in developing markets.

Article • Technology & AI

How AI is transforming cardiovascular healthcare technology

By Helen Sydney Adams

August 05, 2022 • 3 mins

May 31, 2023 — A new report is shedding light on the fast pace of growth in the digital heath sector at present and over the coming decade. In issuing its "Digital Transformation in Healthcare Market Report," Future Market Insights, Inc., forecasted that by the end of 2023, the fast-paced global digital transformation in the healthcare market is expected to be worth $65.2 billion. Its analysis further reported that the market is expected to reach $253.6 billion by 2033, with a 14.5% compound annual growth rate (CAGR) over the next decade.

Digital health has become an increasingly prevalent buzzword due to the increasing implementation of emerging technologies and platforms such as telehealth, mobile health, and other wireless technologies across healthcare facilities and nursing homes that provide patients with real-time medical treatment, according to the market analysis. The recently-released report noted the impact of digital technology has evolved into a game-changing technology in the medical field, as end users' reliance on digital health platforms grows.

GE Healthcare and ACC partner to advance AI in cardiology

9th June 2021 7411

GE Healthcare is collaborating with the American College of Cardiology (ACC) through support of and participation in the ACC's Applied Health Innovation Consortium for the purpose of building a roadmap for Artificial Intelligence (AI) and digital technology in cardiology and developing new strategies for improved health outcomes.

The Consortium brings together academic, clinical, industry, and technology partners and patient advocates, to collaborate in the digital transformation of healthcare and achieve trust in the development of clinical evidence and guidance.

"We are excited to have GE Healthcare join forces with the Applied Health Innovation Consortium," says John Rumsfeld, ACC's chief innovation officer and chief science & quality officer. "In our mission to transform cardiovascular care and improve heart health, GE Healthcare is a great collaborator to help build a roadmap for AI and digital technology that bridges gaps in clinical care."

News | Artificial Intelligence | June 09, 2023

Google Cloud Collaborates with Mayo Clinic to Transform Healthcare with Generative AI

From reimagining enterprise search, to future programs that will transform patient care and research, Google Cloud is putting this new category of artificial intelligence to work for healthcare

Press release

AI to help UK industries cut carbon emissions on path to net zero

New artificial intelligence (AI) solutions will accelerate industrial decarbonisation across the country, with nearly £4 million in government funding for green innovations.

Crowdsourcing AI Solutions for Climate Change: IAEA, ITU, FAO, UNESCO and the World Bank Launch AI for Good Contest for Start-ups

Mary Albon, IAEA Nuclear Sciences and Applications Department

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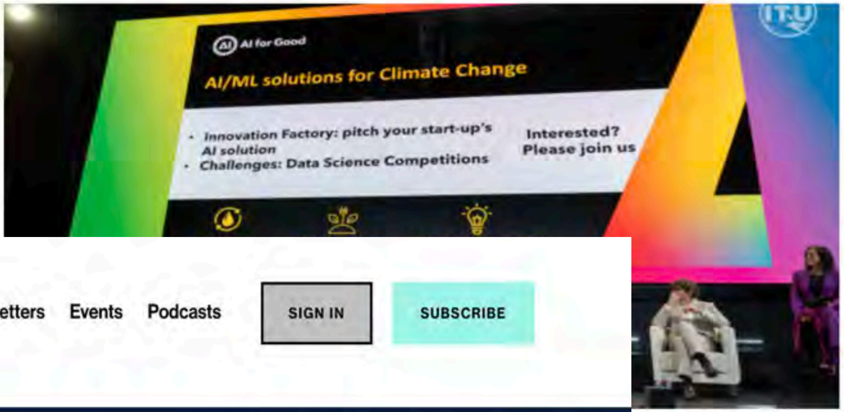

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IAEA Teams up with ITU and UN Family to Promote AI for Good

The role of artificial intelligence and medical imaging in addressing zoonotic diseases

The future of atoms: Artificial intelligence for nuclear applications

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ARTIFICIAL INTELLIGENCE

Here are 10 ways AI could help fight climate change

Machine learning has the potential to make some real inroads against our biggest threat.

By Karen Hao June 20, 2019

Socio-technical imaginaries

- Collectively held, publicly performed visions of desirable futures through science and technology, animated through shared understandings of social life and order
- Creates visions of science and technology as something we want and that is morally good

Expectation theory

- Expectations are performative and not just hype: they drive infrastructure, investment, and funding into particular technologies

Sociologists: how do promises and expectations about technologies gain meaning, traction, and investment? What issues do they hide?

Preliminary evidence.....

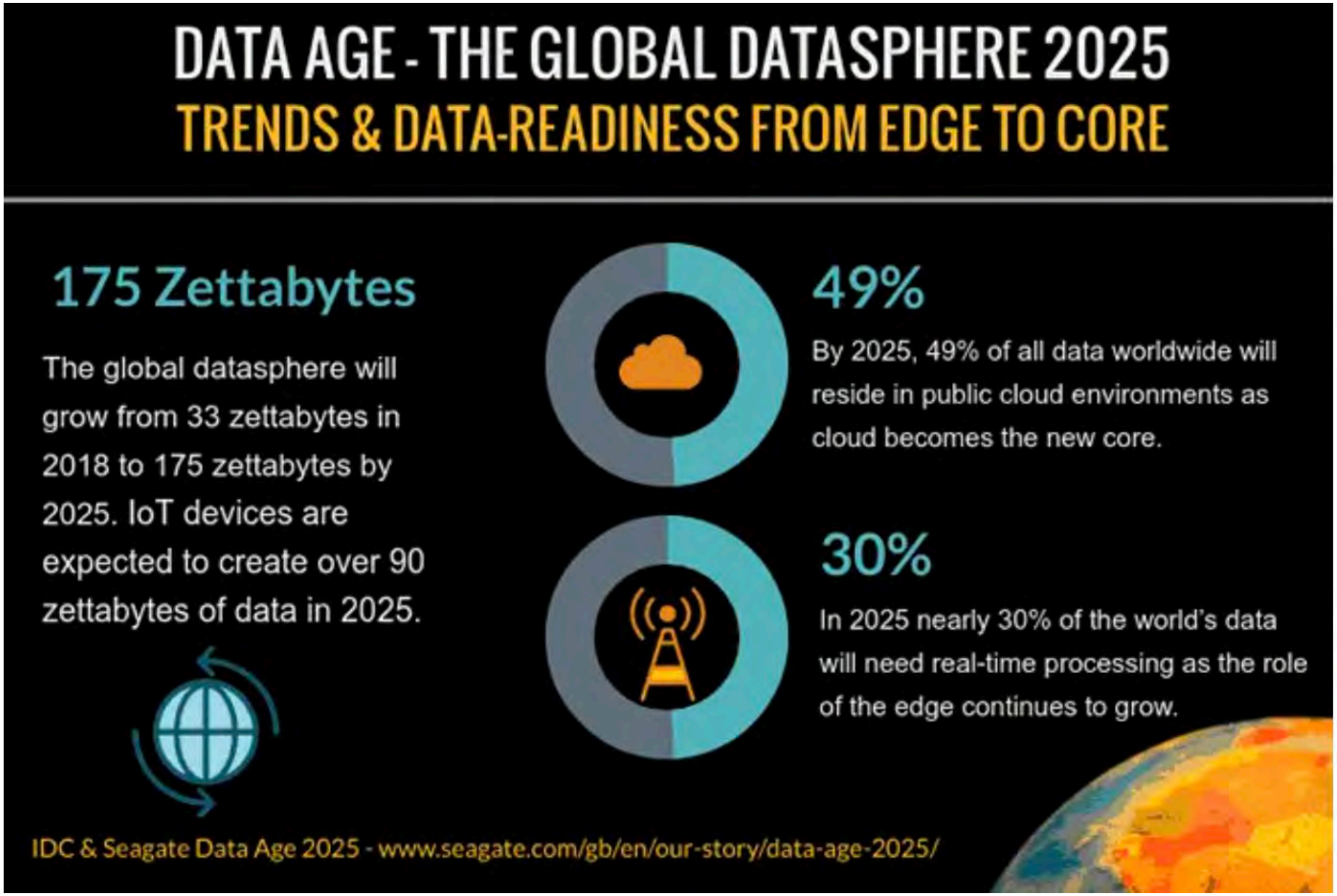
Effectiveness of remote real-time monitoring of patients:

- **post-surgical care** (Jayakumar et al 2020)
- **blood pressure** (NHS England)
- **blood glucose levels** (Lanzola et al 2016)
- **vital signs in pregnancy** (Veena & Aravindhar 2021)
- **cardiac arrhythmia management** (Bawa et al, 2023)

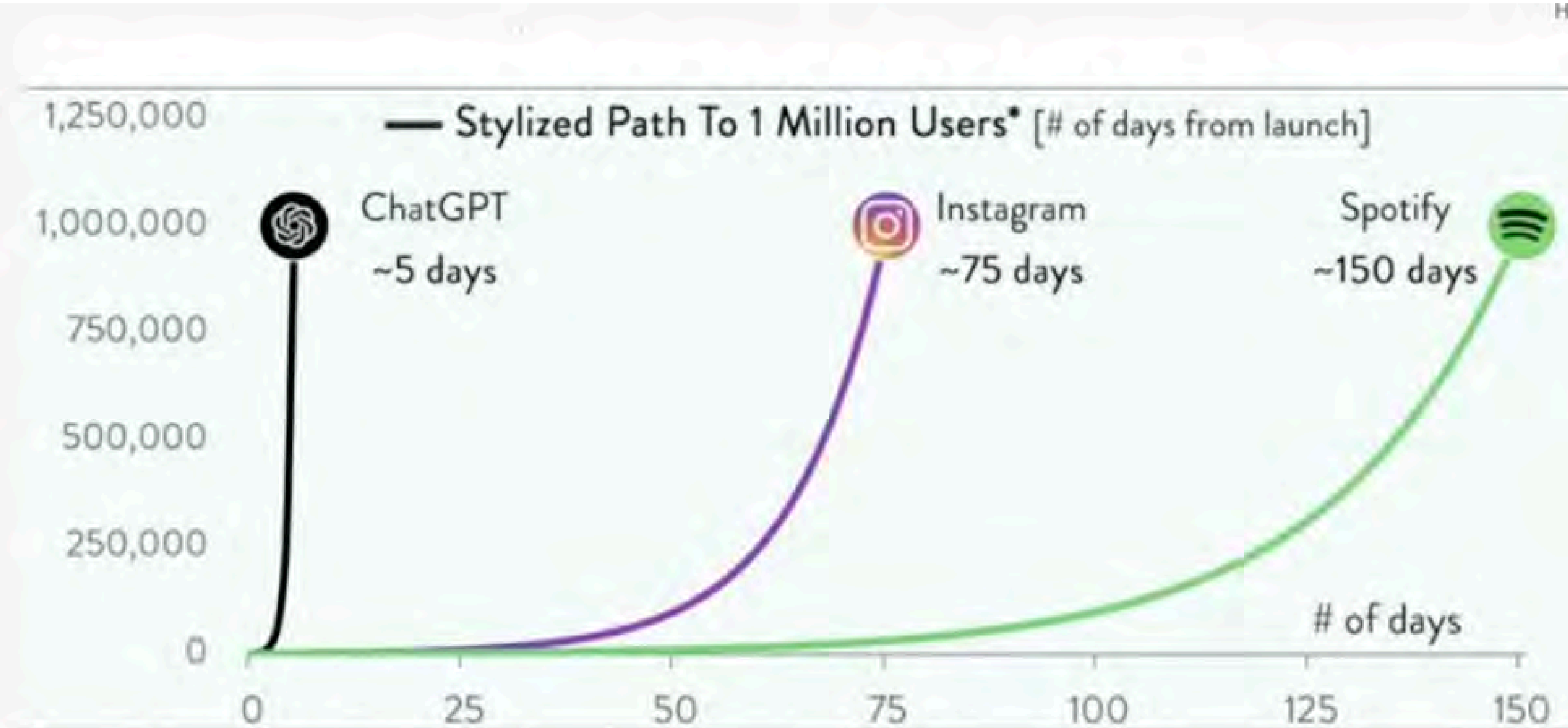
Suggests a useful tool for prevention and decreasing environmental impacts (win-win)

Digitalisation could indeed reduce environmental impacts, but it is also possible that these technologies may be implemented in ways that do not lead to reductions, and/or may increase resource use and other injustices with little change to health outcomes

Growth in Digital Infrastructure



*one zettabyte is equal to a trillion gigabytes



**If you had any doubts that ChatGPT is going to change the way we use the Internet,
It took 30 days to reach 100 million users ….it took Netflix 20 years**

Health data

While healthcare currently has the smallest share of the global datasphere among key industries, it's primed to not just grow the fastest but also surpass the media and entertainment sector and match the financial services sector by 2025.

Growth reflects advancements in healthcare analytics and imaging technology, as well as the increasing amount of real-time data created in medical care.

Healthcare data are among the most private sensitive data

Currently, 37.5% of healthcare data is patient data, and there are predictions that the size of the global healthcare datasphere will exceed the 10ZB level by 2025.

Seagate and IDC

Genomics as an example

- Several NHS-embedded research studies now offer whole genome sequencing (WGS) and whilst only a tiny proportion (often <0.01%) will be analysed to answer health care needs (Horton and Lucassen 2024), the storage costs for WGS are significantly greater than targeted genetic testing.
- WGS of half a million participants in UK Biobank requires about 25 petabytes of storage.
- https://www.genomicsengland.co.uk/initiatives/newborns; https://www.genomicsengland.co.uk/initiatives/100000-genomes-project

UK NHS Spine

- NHS data moved to the cloud because it was increasing at such a pace – so much data!
- Spine supports the IT infrastructure for health and social care in England, joining together over 44,000 healthcare IT systems in 26,000 organisations.
- Handles over 1.3 billion messages a month and at peak times is processing more than 3,200 messages a second.

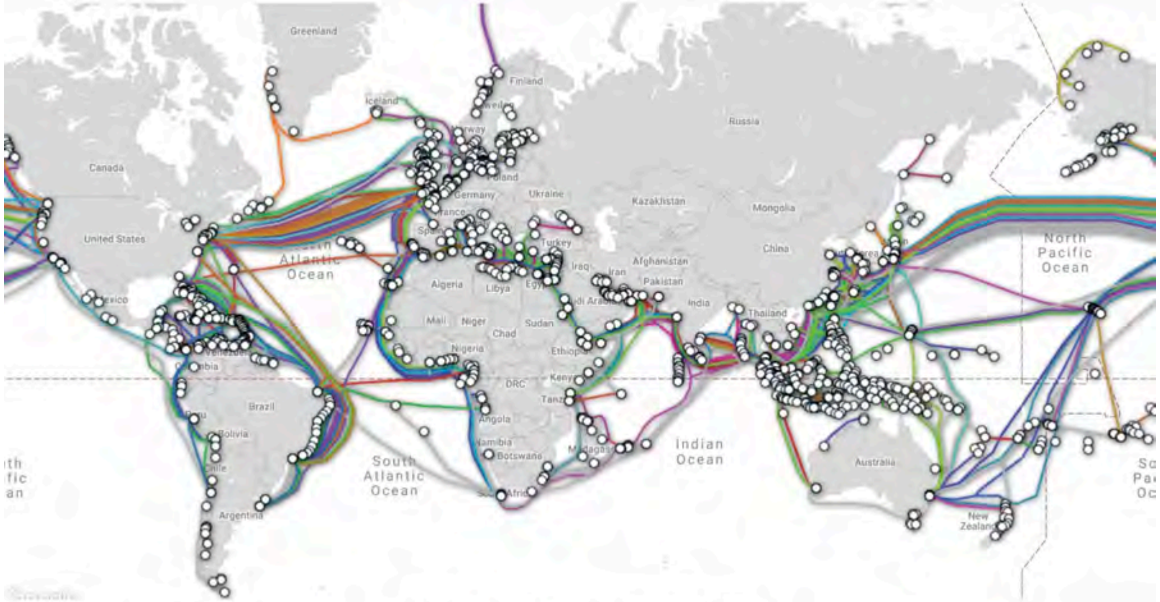
But data/digital is not ‘free’… digital tech: material

Inside DataVita's Fortis data centre in Scotland's central belt

Unhelpful statements on NHS website: “*Spine has moved from being hosted across physical data centres to the cloud*”

https://www.bbc.co.uk/news/technology-67053139?utm_campaign=The%20Week%20in%20Data%20TWID&utm_medium=email&utm_content=278212966&utm_source=hs_email

- [underwater cables]



TeleGeography's Submarine Cable Map (March 2019)

Country	No. of Data Centres
USA	2701
Germany	487
UK	456
China	443
Canada	328
Australia	287
Netherlands	281
France	264
Japan	207
Mexico	153

Digital Technology relies on mining

*extractivist; exploitative; legacies of colonialism

Home > Mining the Landscape > Chapter

Colonial Mining: A Global Historical Context

Geraldine Mate

Earth Day: Colonialism's role in the overexploitation of natural resources

Published: April 18, 2019 5.10pm EDT

Colonial extractions: Race and Canadian mining in contemporary Africa

Canadian mining companies' presence on the African continent and their efforts to disempower indigenous artisanal miners are new iterations of colonial economic systems, said Paula Butler at the latest African Studies Speaker Series.

https://www.raconteur.net/corporate-social-responsibility/cobalt-mining-human-rights/

Digital Tech energy demands

- ICT sector: 1.8-2.8% (1.2-3.9%) global GHG emissions [aviation]
- Big Tech: net zero data centres?
- Power purchase agreements?
- “Follow the sun”: new tech tools to overcome issues?

https://www.orangewebsite.com/articles/data-center-pollution/

For example….AI

TechScape: Turns out there's another problem with AI – its environmental toll

AI uses huge amounts of electricity and water to work, and the problem is only going to get worse – what can be done?

Don't get TechScape delivered to your inbox? Sign up for the full article here

- Training GPT-3 estimated to be have consumed more than 550 tonnes of carbon dioxide equivalent, similar to flying between New York and San Francisco on a return journey 550 times.
- Reporting suggests GPT-4 is trained on around 570 times more parameters than GPT-3, so likely higher cost (though would have had efficiency gains)
- Google has reported that AI represents 10-15% of their power use.

……and also water consumption…

- Training GPT-3 used 3.5m litres of water through datacentre usage (estimated on efficient US datacentres. If it was trained on Microsoft's datacentres in Asia, the water usage balloons to closer to 5m litres).
- ChatGPT estimated to use up to 500ml of water every 20 questions and corresponding answers. GPT-4 likely to be higher.

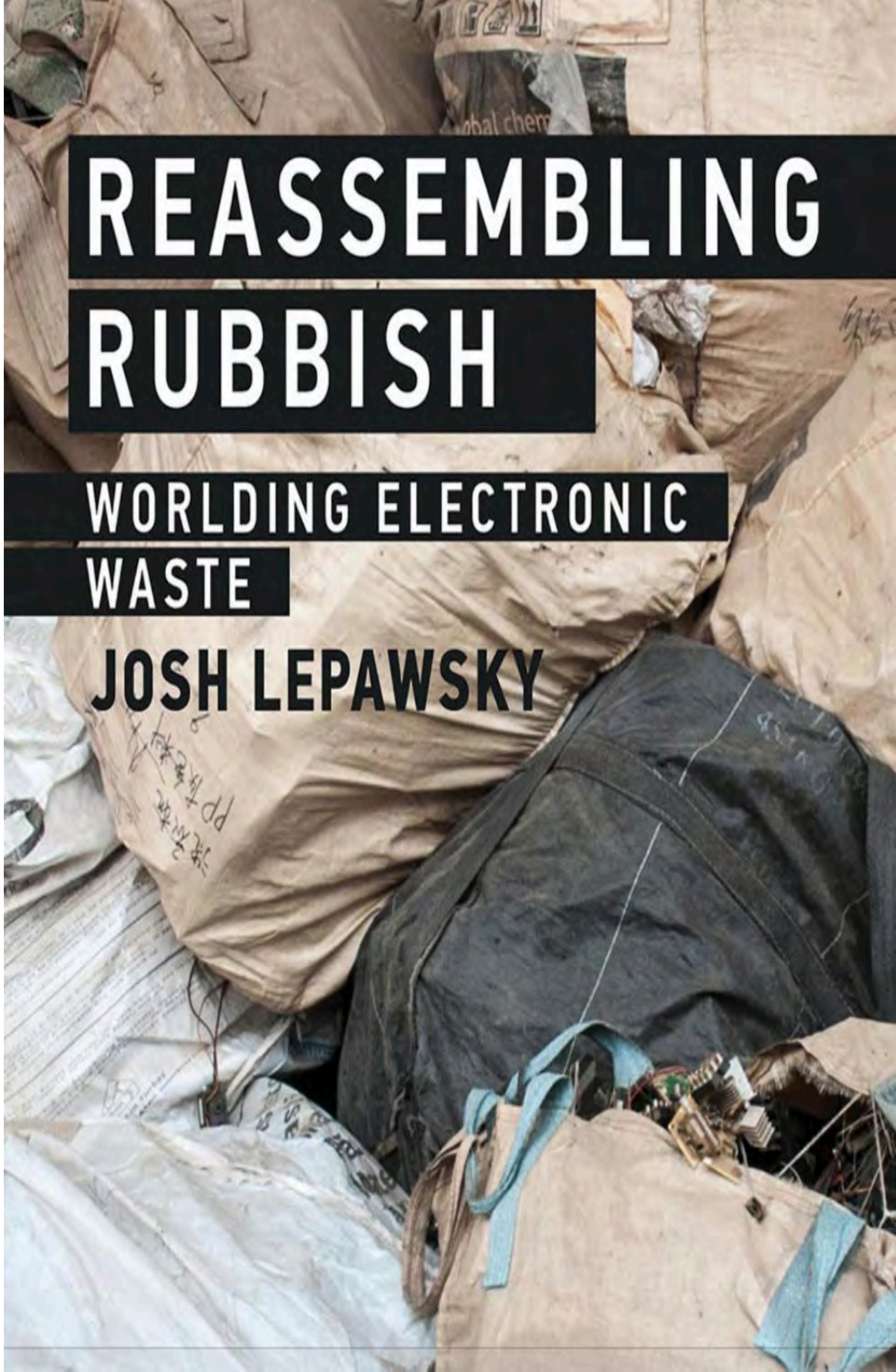
Digital sector’s e-waste

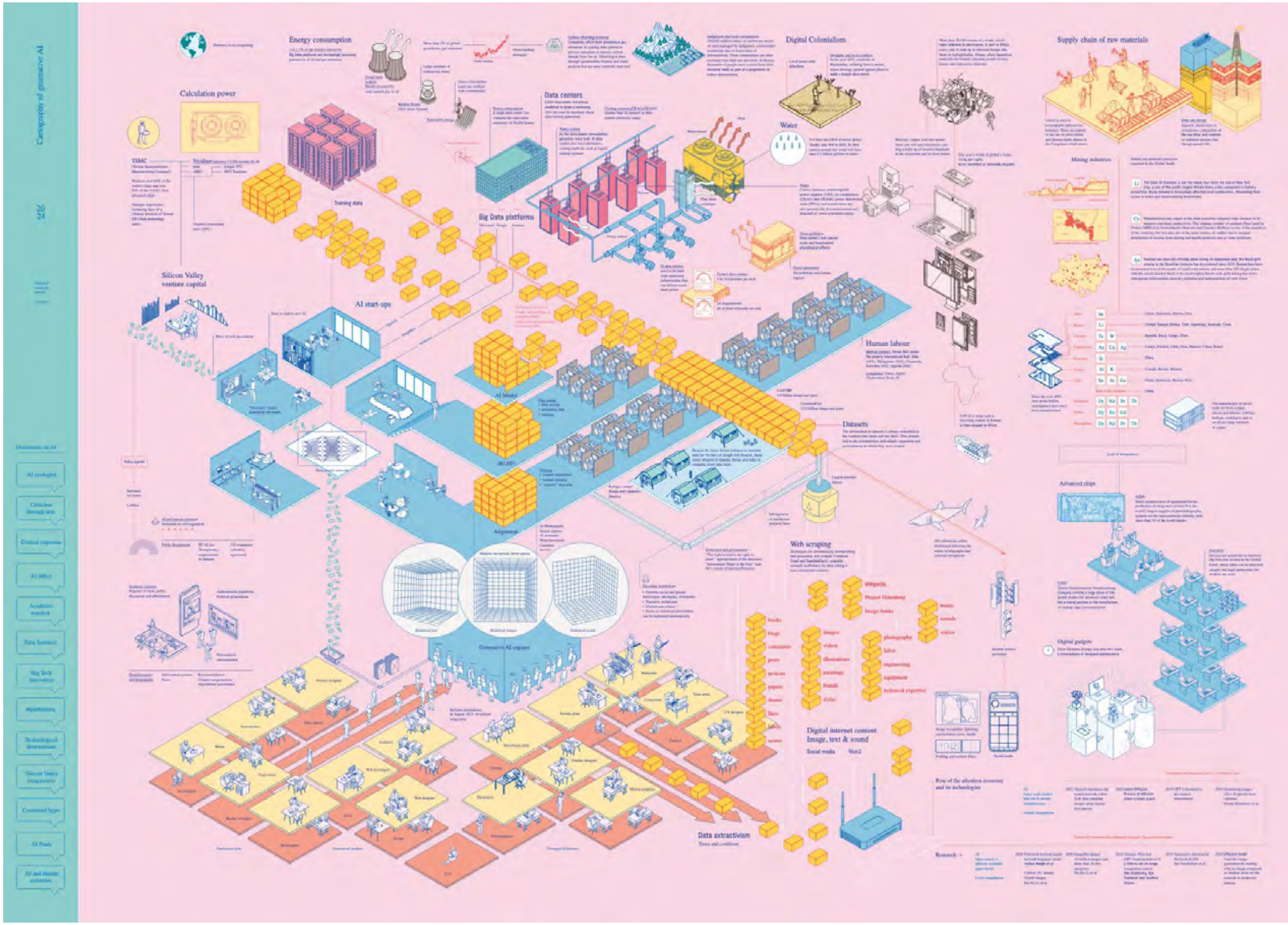
*extractivist; exploitative; legacies of colonialism

https://www.edie.net/news/5/techUK-calls-for-tougher-e-waste-policies-after-illegal-exports-found-to-be-contaminating-food-chains/

….including during manufacturing

eg toxic superfund sites/silicon valley/chip development





Cartography of generative AI

https://cartography-of-generative-ai.net/

Lifecyle of the material and human labour side of AI, marking the physicality of the technology

Many frameworks; guidelines; CO2 calculators to address these issues

NHS Digital code of practice for sustainability

Home / Virtual Care Benefits Calculator

VIRTUAL CARE BENEFITS CALCULATOR

Calculating the financial, environmental, and time saving benefits of choosing virtual care over in-person visits.

Perspective

i-CLIMATE: a "clinical climate informatics" action framework to reduce environmental pollution from healthcare

Dean F. Sittig [1] Jodi D. Sherman [2,3] Matthew J. Eckelman [4], Andrew Draper [5], and Hardeep Singh [6]

We need to think about what power/knowledge these frameworks produce

- Foucault: power is not only repressive but also productive, promoting particular knowledge systems, techniques for regulation, and subject positions

- **Governmentality:**(Foucault 1991): power operates through various techniques, institutions, and discourses to shape and regulate the conduct of individuals/populations. Approaches include, regulation, self governance (the adoption of self-disciplinary practices to conform to societal norms/expectations).

- **Environmentality:** applying governmentality to environmental management. It assumes the *environment is 'not only a biophysical reality, but also a site of power, where truths are made, circulated, & remade'* .

How is power operating?
*interviews; DDAI health researchers

1. ***Self-governance*** in response to societal norms in which power/knowledge circulating in policy, advocacy groups, and media constructs the need to address env issues through the lens of indiv responsibility (‘***responsibilisation of the individual***’ (Rose, 1999)-also links with neo-liberal modes of governance and risk assessment).

2. At the same time, researchers struggle to reconcile tensions between env values/perceived responsibilities (not sure how; other values come first). They hope reconciliation can come from ***regulation/obedience***.

3. **<u>Drawing on wider literature: </u>**regulation produces knowledge through metrics/evaluation rqments (site of knowledge production). This knowledge shapes practice by giving power to a specific meaning of sustainability. This meaning then governs the way in which we conduct ourselves e.g. if we use carbon calculators then we generate more knowledge about carbon. Carbon accounting has been heavily critiqued….

4. **<u>In fact, interviewees already identified different meanings of sustainability in research:</u>**

5. **<u>Concerns include</u>**:

   A. Governing through regulation can be **de-contextual;** tick-boxing; compliance rather than embodied. *eg of alternative: regulation that supports *what* type of research is conducted not *how* it is conducted (e.g., funding streams (Jamieson, 2015)).

   B. Other meanings loose power. e.g., those in which knowledge production is harder or more messy.

- Carbon calculators *‘are a form of rule that has given rise to particular ways of ‘seeing’ and ‘knowing’ the climate’* (Lövbrand, 2011).
- These ways of ‘seeing’ and ‘knowing’ are not a neutral mirror of nature, but are socio-political artefacts that become self-fulfilling sites of knowledge/power that are performative: their *‘epistemic authority makes us see the world in a specific way that makes possible specific ways of acting upon’.*
- Within this way of seeing the world, new tools and actors involved in knowledge generation emerge, expanding the power of this regime of rationality.
- We see this through the production of tools/actors that draw on carbon calculators to generate new forms of knowledge, for example, knowledge about how to optimize digital pipelines and/or algorithmic design, knowledge about how to assess carbon calculations on act on it

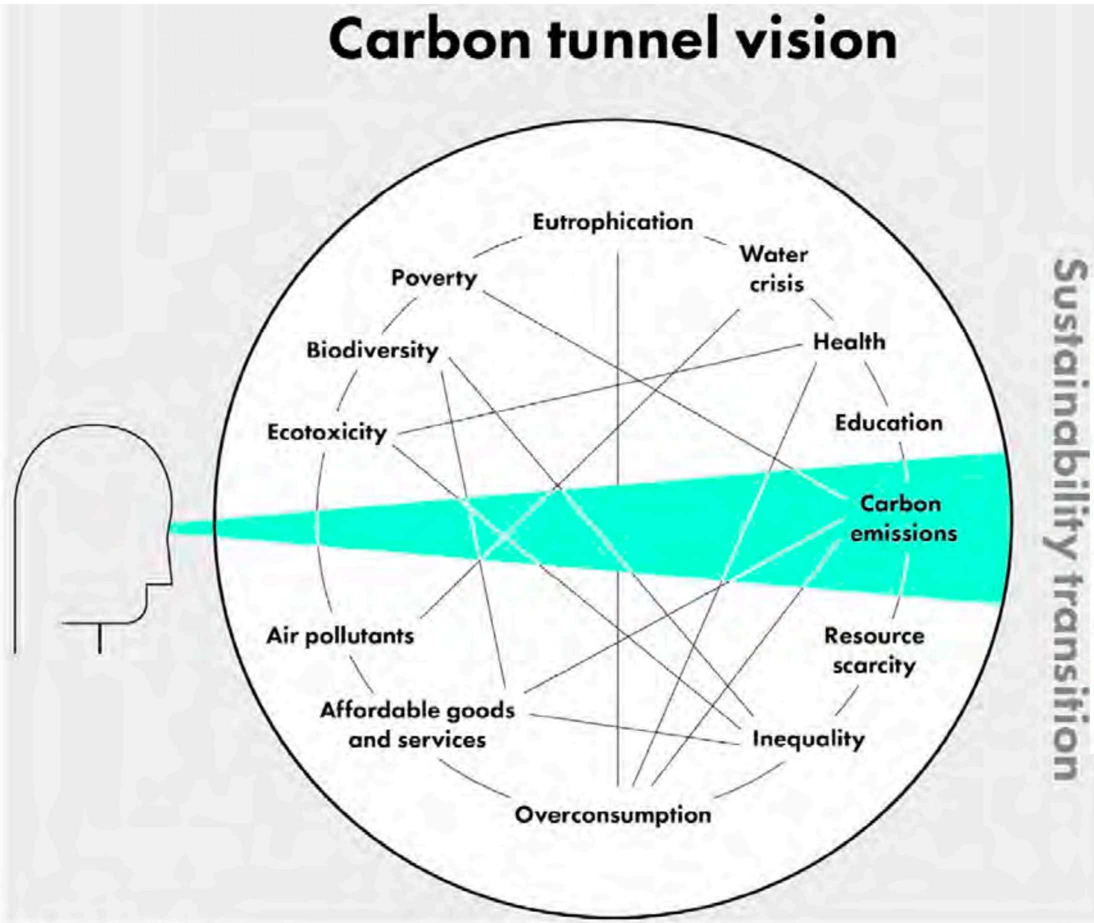


Fig 1. Carbon tunnel vision [2].

https://doi.org/10.1371/journal.pgph.0001684.g001

REVIEW

Breaking free from tunnel vision for climate change and health

Thilagawathi Abi Deivanayagam[1,2‡*], Rhiannon Elizabeth Osborne[3‡]

1 Institute for Global Health, University College London, London, United Kingdom, 2 Lancaster Medical School, Faculty of Health and Medicine, Lancaster University, Lancaster, United Kingdom, 3 School of Clinical Medicine, Addenbrooke's Hospital, University of Cambridge, Cambridge, United Kingdom

‡ TAD and REO are joint first authors.
* abi.deivanayagam@ucl.ac.uk

Abstract

How is power operating?
*interviews; DDAI health researchers

1. ***Self-governance*** in response to societal norms in which power/knowledge circulating in policy, advocacy groups, and media constructs the need to address env issues through the lens of indiv responsibility ('***responsibilisation of the individual***' (Rose, 1999)).

2. At the same time, researchers struggle to reconcile tensions between env values/perceived responsibilities (not sure how; other values come first). They hope reconciliation can come from ***regulation/obedience***.

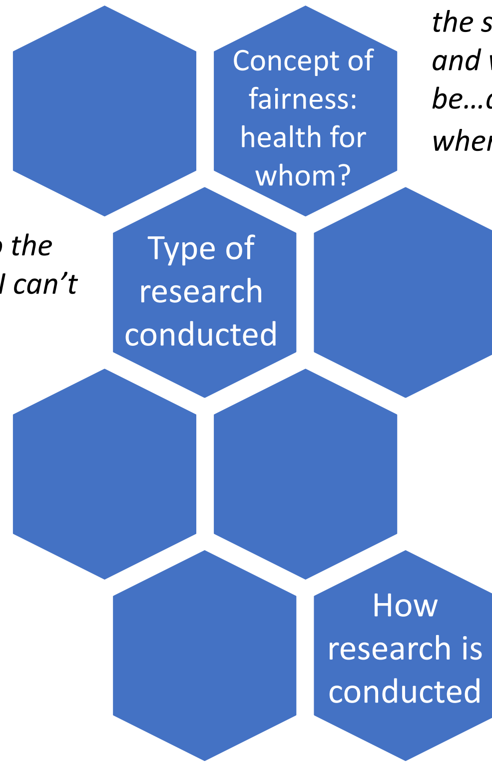
3. **<u>Drawing on wider literature:</u>** regulation produces knowledge through metrics/evaluation rqments (site of knowledge production). This knowledge shapes practice by giving power to a specific meaning of sustainability. This meaning then governs the way in which we conduct ourselves e.g. if we use carbon calculators then we generate more knowledge about a specific way to measure carbon emissions (there are many ways to measure carbon

4. **<u>As an example, interviewees already identified different meanings of sustainability in research:</u>**

5. **<u>Concerns include</u>**:

   A. Governing through regulation can be **de-contextual;** tick-boxing; compliance rather than embodied. *eg of alternative: regulation that supports *what* type of research is conducted not *how* it is conducted (e.g., funding streams (Jamieson, 2015)).

   B. Other meanings loose power. e.g., those in which knowledge production is harder or more messy.



the science community has got to be better…we're chasing AI and what can this do for health….when the impact of that will be…quite negligible and…the impact for the people who live where the [resources for the] technology comes from…. (23)

sustainability, I think comes second to the scientific question. You can't say, "oh I can't ask this question . ..[..]..' (17)

Better efficiency/data storage practices (resonates w guidelines)

How is power operating?
*interviews; DDAI health researchers

1. ***Self-governance*** in response to societal norms in which power/knowledge circulating in policy, advocacy groups, and media constructs the need to address env issues through the lens of indiv responsibility ('***responsibilisation of the individual***' (Rose, 1999)).

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3. **Drawing on wider literature:** regulation produces knowledge through metrics/evaluation rqments (site of knowledge production). This knowledge shapes practice by giving power to a specific meaning of sustainability. This meaning then governs the way in which we conduct ourselves e.g. if we use carbon calculators then we generate more knowledge about carbon, which can lead to carbon tunnel vision

4. **In fact, interviewees already identified different meanings of sustainability in research**

5. **Concerns include**:

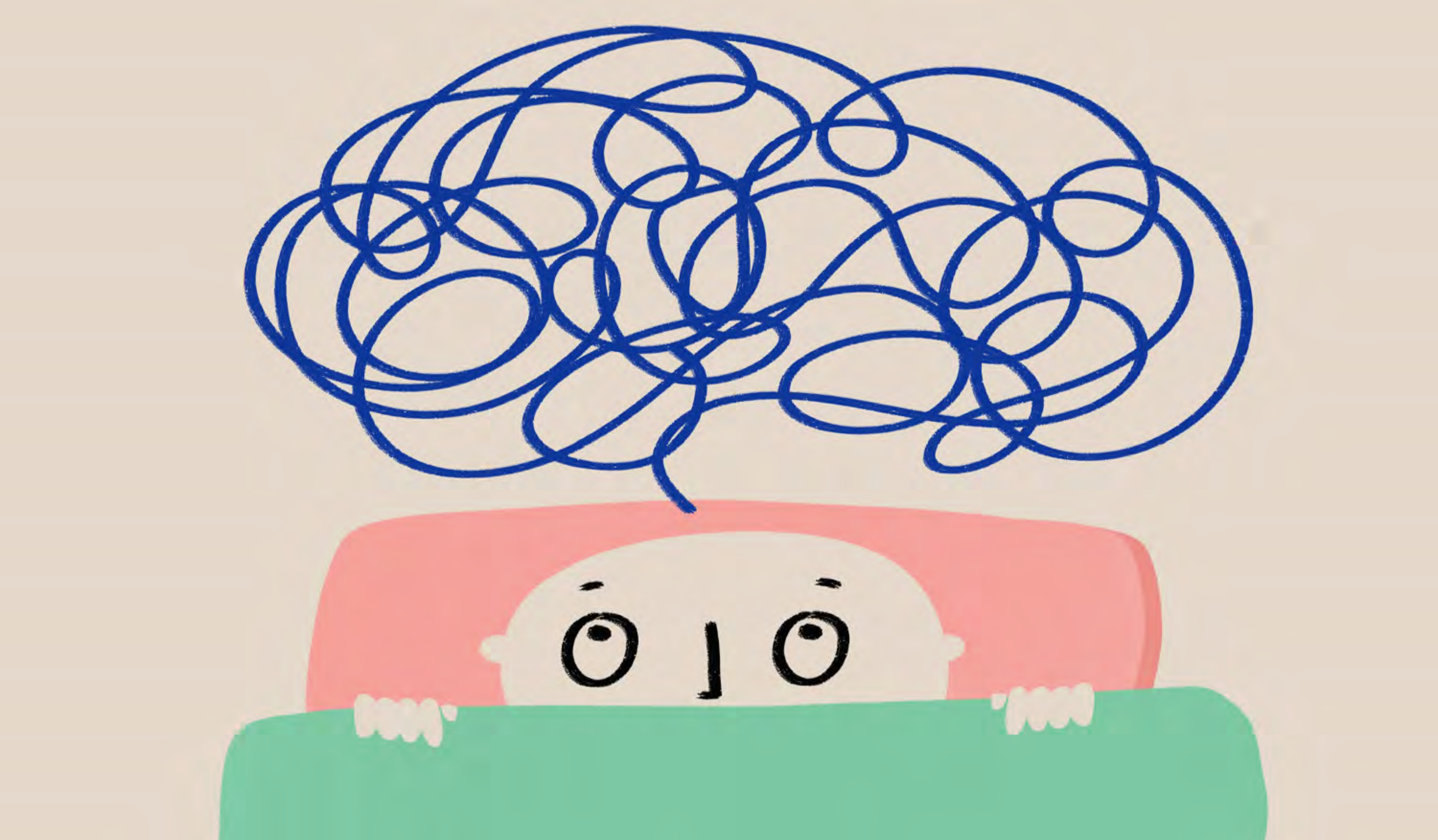
    A. Governing through regulation can be **de-contextual;** tick-boxing; compliance rather than embodied. [Consent is an example of this: consent as a proxy for ethics]

    B. Other meanings loose power. e.g., those in which knowledge production is harder or more messy.

BUT structure means ignoring the wider picture

-Facebook example…complexity of measuring

-Messiness…..



Rebound & revenge effects

Efficiency gains are not enough….

- Over the last half a decade, improvements in digital capabilities have allowed for increasing efficiency so that energy and resource consumption has not increased in line with our growing appetite to gather and process evermore data. However, efficiency gains will likely soon no longer be enough to offset our drive to create and gather ever more data.
- This is not helped by the private sector/markets….

- The need for bigger and bigger AI models as an example
- A On average, large-scale AI models use about 100 times more compute than other contemporaneous AI models.[53] If model sizes continue growing along the current trajectory, some estimates place compute costs in excess of the entire US GDP by 2037.[54] Despite this, AI models keep getting larger because size is now correlated with capability. Competition in the market for large-scale AI models remains closely tied to the scale of the model: while factors including data quality and training method are important influences on model performance, anyone wishing to compete in the market for large-scale AI models will have to end up building larger models than the current state of the art. Those seeking to build AI systems for particular use cases won't necessarily need to build new models from scratch—but they will be reliant on hosted models or access to APIs that, as a rule, flow through a contract with one of the major cloud infrastructure providers.
- https://ainowinstitute.org/publication/policy/compute-and-ai#h-how-is-the-demand-for-compute-shaping-ai-development

Furthermore, the energy policy sector has demonstrated that behaviour often changes in response to perceived cost and energy savings, and this can lead to energy savings being less than expected. The phenomenon is called a **rebound effect,** and one that increases energy usage overall is called **backfire**

- As datasphere grows, more energy is required.
- Combined electricity use by Amazon, Microsoft, Google, and Meta more than doubled between 2017 and 2021
- Digital sector's proportion of global electricity usage will increase as other sector's de-carbonise

- Rebound/revenge effects.
  - Consumption increases (bigger AI models)
  - Other unintended revenge effects
  - e.g. ride sharing increased cars on the road
  - e.g. cleaning park benches with water (Anne-Marie Mol)
  - e.g. insulation in roof; less worried about closing doors

- *Turning up the heating, opening windows in stuffy rooms or building extensions could all contribute.*

‘Rebound effect’ cancels out home insulation’s impact on gas use – study

Research in England and Wales shows that conservatories, extensions and changing behaviour cancelled out any savings

Loft insulation saves money on bills, but is no ‘magic bullet’ for the energy crisis. Photogr
DWImages/Alamy

Conservatories and house extensions could be helping to wipe out the reductions in gas use secured by insulating homes, according to a study found insulation only provides a short-term fall in energy consumption

Patterns

CellPress

Volume 4, Issue 2, 10 February 2023, 100679

Perspective

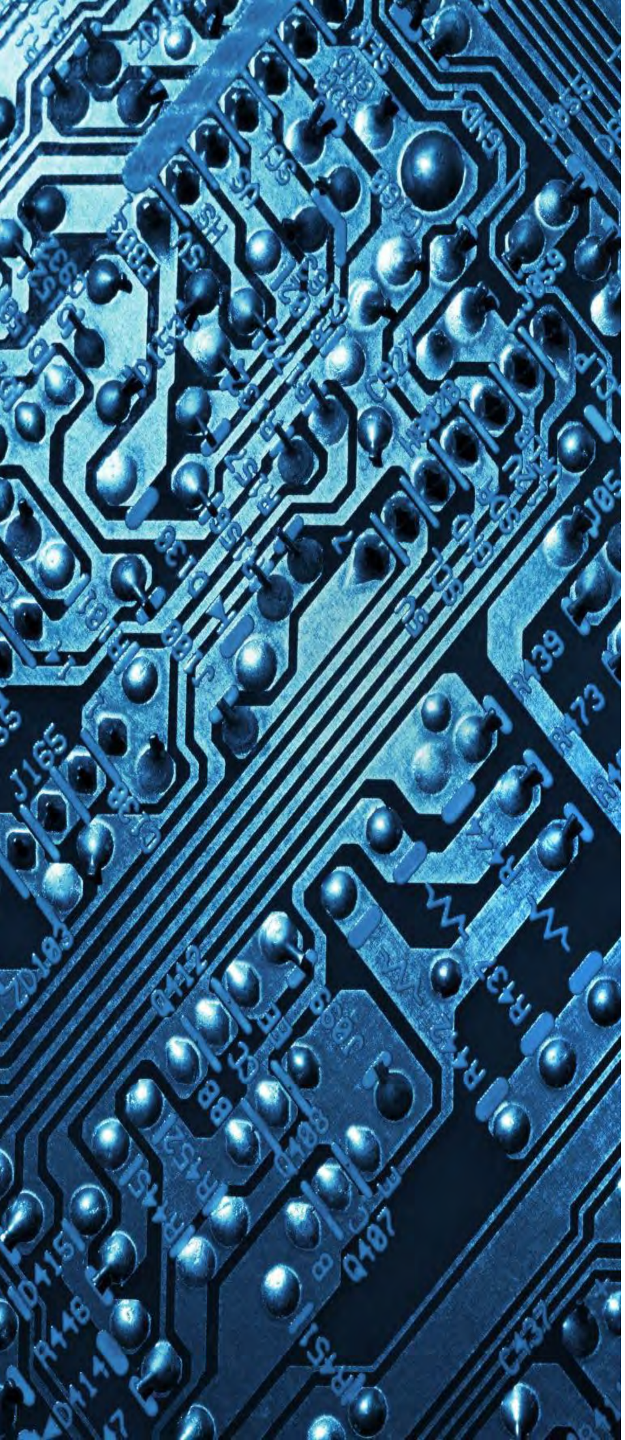
Systems thinking and efficiency under emissions constraints: Addressing rebound effects in digital innovation and policy

Kelly Widdicks[1], Federica Lucivero[2], Gabrielle Samuel[3], Lucas Somavilla Croxatto[2 4], Marcia Tavares Smith[1], Carolyn Ten Holter[2], Mike Berners-Lee[5], Gordon S. Blair[1 6], Marina Jirotka[2], Bran Knowles[1], Steven Sorrell[7], Miriam Börjesson Rivera[8], Caroline Cook[9], Vlad C. Coroamă[10], Timothy J. Foxon[7], Jeffrey Hardy[11], Lorenz M. Hilty[12], Simon Hinterholzer[13], Birgit Penzenstadler[14 15]

Show more

It’s not just about environmental impacts, but also about the usefulness of the data

- Whether digital/data analytics will lead to better health needs questioning.
- There’s no doubt that it may/is effective in many circumstances, but there are a few things that need considering….



CONCERNS

- Digital tech pushes problems to be framed as solvable by digital interventions detracts attention from the need for other measures
  - *e.g. delivery drivers; toilet (Becker; insolvent)*
  - *Apps to measure pollution rather than addressing pollution*

- Tempted to believe only way to achieve a healthy future is through more data/analytics
  - in part, driven by pace of private sector: data infrastructures being developed even before we know we need/want them. Once there, we use them–and want more of them.

- Deferral/procrastination of addressing issues: “we need more data” (social determinants?)

Data fetishism

- Narrows our views of what ‘being healthy’ means. We view the promotion of better health outcomes as being equated with monitoring, analysing and assessing as many of our everyday lives as possible.
    - Ignore experiential knowledge? Less epistemic value? [what is personalised medicine? [**Prainsack**]

- With such a fixation on the need for data to improve health, sometimes it’s easy to forget that the very act of data accumulation and analytics cannot and will not produce health benefits on its own.
- **No benefits = wasted resources**
- Clinical trials?

Ways forward…

- If using digital technologies:
- Consider env impacts
- Consider efficiency with constraints
- Monitor revenge effects of digital tech

How do we get there?

Thematic analysis of tools for health innovators and organisation leaders to develop digital health solutions fit for climate change

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ABSTRACT

Objectives While ethicists have largely underscored the risks raised by digital health solutions that operate with or without artificial intelligence (AI), limited research has addressed the need to also mitigate their environmental footprint and equip health innovators as well as organisation leaders to meet responsibility requirements that go beyond clinical safety, efficacy and ethics. Drawing on the Responsible Innovation in Health framework, this qualitative study asks: (1) what are the practice-oriented tools available for innovators to develop environmentally sustainable digital solutions and (2) how are organisation leaders supposed to support them in this endeavour?

Methods Focusing on a subset of 34 tools identified through a comprehensive scoping review (health sciences, computer sciences, engineering and social sciences), our qualitative thematic analysis identifies and illustrates how two responsibility principles—environmental sustainability and organisational responsibility—are meant to be put in practice.

Results Guidance to make environmentally sustainable digital solutions is found in 11 tools whereas organisational responsibility is described in 33 tools. The former tools focus on reducing energy and materials consumption as well as pollution and waste production. The latter tools highlight executive roles for data risk management, data ethics and AI ethics. Only four tools translate environmental sustainability issues into tangible organisational responsibilities.

Conclusions Recognising that key design and development decisions in the digital health industry are largely shaped by market considerations, this study indicates that significant work lies ahead for medical and organisation leaders to support the development of solutions fit for climate change.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Innovators in the digital health field are asked to develop solutions that are not only clinically safe and efficient, but also meet increasingly complex responsibility and environmental sustainability principles.

WHAT THIS STUDY ADDS

⇒ There is a lack of practice-oriented tools that can guide organisational leaders in supporting innovators developing environmentally sustainable digital health solutions.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Scholars, policymakers and practitioners can draw from the Responsible Innovation in Health framework to develop practice-oriented tools that can guide innovators and organisation leaders along a new innovation pathway fit for 21st century challenges to our health.

INTRODUCTION

The digital health field has exponentially grown over the past decade as innovators tackle pressing 21st century health challenges and Industry 4.0 technologies (eg, Internet of Things, robotics, cloud computing) expand ways to deliver healthcare. While the field ascribes a central role to data in healthcare, positing that 'data can help save lives around the world',[1] ethicists and civil society increasingly draw attention to the significant risks new digital technologies, especially those operating with artificial intelligence (AI), may raise (eg, privacy, bias, discrimination).[2–5]

Furthermore, the 'data as saviour' narrative sharply contrasts with the calamitous discourse surrounding the impact of the climate crisis on human and planetary health. Experts urgently call for a steep reduction of healthcare's carbon footprint and to place environmental sustainability at the forefront of all healthcare.[6–8] For instance, the International Leadership Group for a Net Zero National Health System (NHS) England invites the 80 000 global medical device suppliers of the NHS 'to decarbonise their operations by 2045 at the latest'.[9] Thus, to deliver on the promises of widespread benefits while limiting risks, digital health solutions must be safe, effective, ethical, and environmentally sustainable.[4–6 10–15]

These multiple demands place the digital health field in a difficult position. Health innovators must not only meet rigorous clinical safety and efficacy standards when developing new solutions, they must also account for complex responsibility principles (eg, explainability, accountability, transparency)[16–18] and find ways to reduce the environmental impact of their solutions. The latter is a challenging endeavour as the digital industry (hardware, software, infrastructures, supply chain) is one of the most polluting industries,[6 12 13 19] key design and development decisions are largely taken outside of the health field, environmental issues remain beyond the peripheral vision of digital

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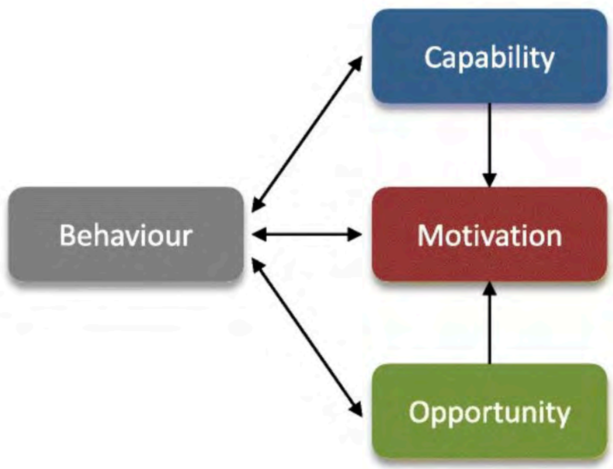
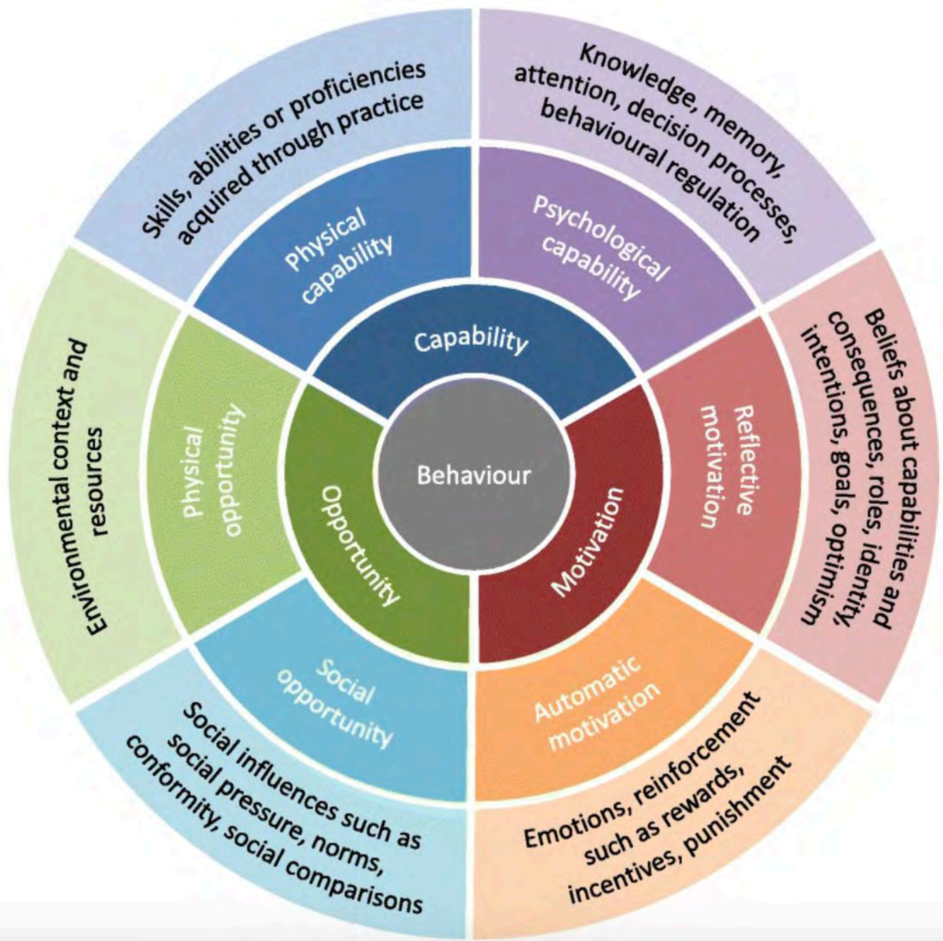
…Behaviour change models are a good starting point….





…though what/whose behaviour do we want to change?

- **Health care guidelines now include environmental impact considerations……**

- <u>Clinician level</u>: World Medical Association's International Code of Medical Ethics: '[t]he physician should strive to practise medicine in ways that are environmentally sustainable with a view to minimising environmental health risks to current and future generations.'

…but not inline with public perceptions

UK public perceptions for change (12 focus groups)

- Change should be:
  - **Beyond carbon**; also consider plastic waste; toxic waste etc
  - **Increasing efficiency** in care pathways, not as a criterion in decision-making
    - **Health comes first**
      - Clinicians should be focusing on me
  - Importance of **reducing stress/exhaustion** of HCP and patient
  - Operational change; government; socio-politics

So what issues still remain at the operational level…?

- How can the health system responsibilities contend with massive global trade networks, as is the case with e-waste and mining? Every change will have a knock-on effect…Also, viewing them solely through a health perspective ignores the ’liveliness’ of e-waste dumps (Peter Little)? [regulatory solutionism]

- If regulations are imposed will it lead to compliance-based approaches – ‘responsibilisation of the individual’ (Rose, 1999)?

- How to address tensions between other priorities

- How to address systems issues and rebound/revenge effects

- **Is it just about doing something rather than everything?**

The opportunity

Digital technology has the potential to help us understand and act on climate change

The risk

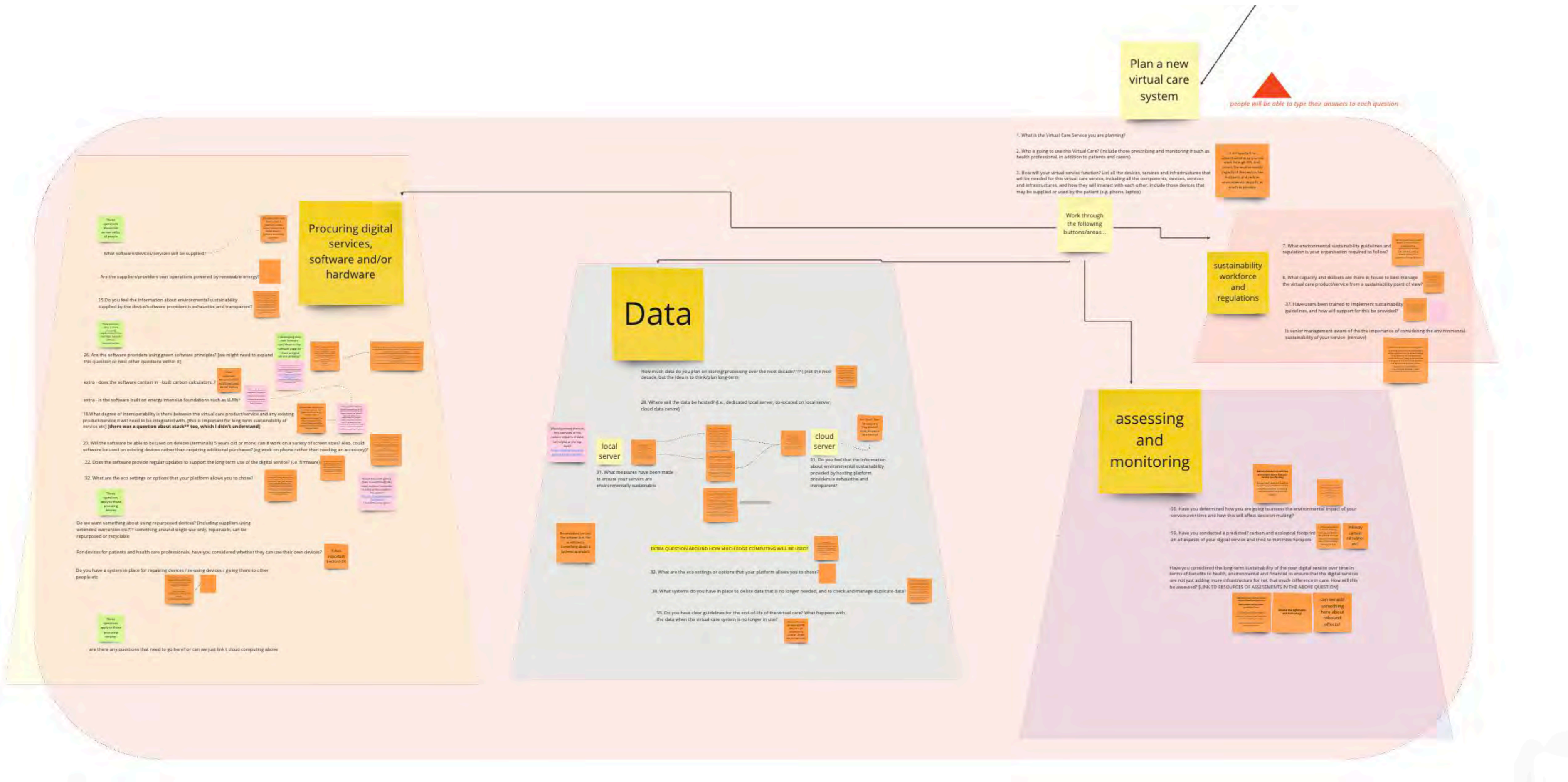
Digital technology has it's own carbon footprint which is steadily increasing

Creating a solution

PARIS-DE is creating a framework for the sustainable and responsible innovation of digital technology in-line with the Paris Agreement

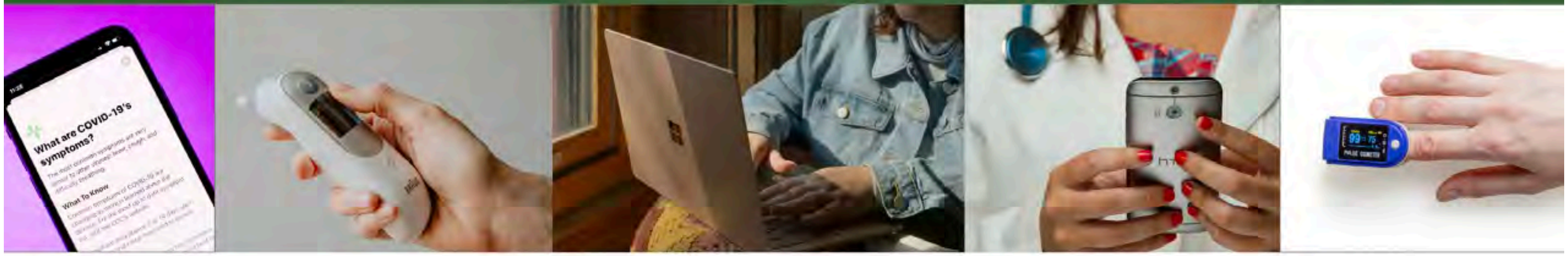
https://wp.lancs.ac.uk/paris-de/about-paris-de/

No answers (like medical ethics), but worth asking questions



-Different case studies
-Different needs of users e.g. VC needs to be digestible and useful
-Developing prototype of tool to achieve this
In this case, it's around having questions to ask…

Name of the tool: What questions to ask when planning Virtual Care



What is this tool?

This is a tool to help you reflected on the choices you will need to make if you are planning to choose and implement an environmentally sustainable Virtual Care in your organisation.

We identified lists of questions for five stages of the planning and implementation process. This questions might be answered by yourself and other members of your team, or you may need to ask them to potential providers and suppliers of the products, services and systems that will form your Virtual Care service. It is not always possible to find answers to all questions. This tool should support you in navigating the uncertainty regarding the environmental impacts of digital innovations.

How to use it

You might already have answers to some of these questions. For others, you will be able to work out answers with the help of other people involved in your project. However, don't be put off by questions to which you have no answers. Make a note of it as an area for further development and continue using the tool to identify and reflect on the potential

Why are you here?

Envisioning a VC system

Wanting to ensure your VC system is environmentally sustainable

Wanting to ensure your VC system is environmentally sustainable

paris de

1. What is your Virtual Care Service?

2. Who uses your Virtual Care? (Include those prescribing and monitoring it such as health professional, in addition to patients and carers)

3. How does your virtual service function? i.e., what are all the components, devices, services and infrastructures that will be needed for this virtual care service? And how do these devices, services and infrastructures relate to each other

Sustainability workforce and regulations

assessing and monitoring

Data

Digital services, software and/or hardware that you

3

THE BOUNCING COIN

Could your intervention result in someone saving money? This saving could be spent using your product/service more intensively, or to pay for carbon-intensive activities (flying to holidays, buying brand new stuff, etc.).

REBOUND EFFECTS

3

THE BOUNCING TIME

Could your intervention allow someone to save time? This could allow them to use your product/service more intensively, or to spend that time on carbon-intensive activities...

REBOUND EFFECTS

3

EXCESSIVE ACCESSIBILITY

Could your intervention make it more convenient for someone to access something? This could allow them to use it more intensively or more often...

REBOUND EFFECTS

3

THE CHICKEN OR THE EGG

Your product/service might use an existing infrastructure, but would that infrastructure exist without products/services like yours?

REBOUND EFFECTS

3

THE HIJACKING (MISUSE)

Could some people misuse this product/service/rule for their own benefit (e.g. to make money)? Think about the possible weaknesses (you can role-play the "bad guy").

REBOUND EFFECTS

3

PANDORA'S BOX

Could your intervention open the door to new technologies, products or services that will have a negative impact (e.g. autonomous cars)?

REBOUND EFFECTS

3

THE COBRA

If you're faced with a cobra invasion and you reward anyone who brings in a dead cobra to deal with it, you run the risk of ending up with cobra farms.

REBOUND EFFECTS

3

DUMBING IT DOWN

Could your intervention make an interaction easier requiring a lower level of skills for someone to use something? This could enable new groups of people to use it...

REBOUND EFFECTS

1

Problem

Data centres use large amount of energy to power its servers producing a large amount of carbon emissions.

Intervention

Substituting the provision of energy from fossil fuels to renewable energy.

Intervention conducted by

Owner/manager of the Data Centre.

Main stakeholders

Service users, data centre employees, communities in the vicinity of data centre.

Some of the possible rebound effects

- Perception that swapping to renewable energy cause fewer carbon emissions (Lighter Soul) ends up increasing the use of the data centre.
- The change to renewables attracts new business customers.
- Extra revenue enables data centre owner to invest it in a new building and equipment for a data centre expansion (Bouncing Coin).
- New business customers increase their provision of digital services stimulating the demand for more data centres and the economy in general (Pandora's box).

Some of the possible mitigation strategies

- Campaign to raise awareness showing that renewable energy also has a carbon footprint.
- Data centre owner invests extra revenue to improve environmental sustainability performance of existing facilities (Spend that Money) or donates to sustainability charities (Spend that Money).
- Data centre adopt new management procedures to reduce idle servers, for example, sharing racks amongst different business customers to delay or prevent the need to increase capacity (Business Modelling).

EXAMPLE: DATA CENTRE POWER FROM FOSSIL FUEL TO RENEWABLE ENERGY

Photo by Moritz Kindler on Unsplash

SHADE sits at the intersection of **S**ustainability, **H**ealth, **A**I, **D**igital technologies and the **E**nvironment.

SHADE is guided by a fundamental question: How should the balance between AI/digital enabled health and planetary health be struck in different areas of the world, and what should be the guiding principles?

To address this SHADE promotes interdisciplinary enquiry to understand and make visible sustainable practices situated in specific geographical and societal contexts. Undertaking both normative and solutions based research, SHADE draws on empirical, epistemic and ethical perspectives from philosophy, law, sociology and ethics, as well as from more quantitative approaches such as life cycle sustainability assessment. See more about SHADE here.

SHADE was formed in September 2023 and has a global membership that includes academics as well as societal actors. Its founding members are already working on relevant projects listed under the Projects tab below.

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Thank you

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Workshop on Principles & Priorities for Environmentally Sustainable Digital Health

Tuesday, April 23 – Wednesday, April 24, 2024
Toronto, Ontario

Tuesday, April 23: Faculty Club

TIME	ACTIVITY
5:00-5:30pm	**Reception**
5:30-5:45pm	**Land Acknowledgement & Welcoming Remarks**
5:45-6:15pm	**Introductions**
6:15-6:45pm	**Setting the Stage**
6:45-8:30pm	**Dinner**

Wednesday, April 24: MaRS Collaboration Room 3

TIME	ACTIVITY
8:15-8:45am	**Registration & Breakfast**
8:45-9:15am	**Traditional Opening & Welcoming Remarks**
9:15-10:15am	**Keynote Presentation** *Dr. Gabby Samuel*
10:15-11:15am	**Small Group Activity: The Promises & Perils of Digital Health** *Built-in break*
11:15am-12:15pm	**Crowd Sourcing Solutions**

12:15-1:00pm	**Lunch & Prioritization Activity**
1:00-2:00pm	**Small Group Activity: Addressing Roadblocks**
2:00-2:15pm	**Break**
2:15-3:00pm	**Reporting Back**
3:00-3:45pm	**Consolidation of Consensus & Next Steps**
3:45-4:00 pm	**Closing Remarks**