# Designing digital health applications for climate change mitigation and adaptation

## Environmentally sustainable equitable digital transformation is central to delivering low carbon health care models

Digital health, an integrated approach using digital technologies and platforms to improve health care outcomes, has emerged as a key tool to reduce health care's approximately 5% share of global greenhouse gas emissions[1] and to address the impact of climate change on health. When the National Health Service (NHS) England committed to reducing its carbon footprint to net zero by 2040, it indicated that digital transformation is central to delivering low carbon health care models.[2] However, this mitigation of emissions from health care is yet to be realised due to different maturity levels of digital health technology (DHT) integration worldwide.[3] So, how can low carbon models of care be achieved through digital health, and what are the implications for digital health service design and delivery? How can digital solutions be adapted on the principles of sustainability, ecology, and equity in order to effectively address the impacts of climate change on health?

### Mitigating the carbon impact of digital health technology

Even though the direction of NHS England suggests that DHT can assist health care systems to reduce their carbon footprint,[2] the environmental effects of DHT are challenging to address, as they go beyond the confines of hospitals and traditional care settings. These effects touch on the digital health consumer, the supply chains of DHT production and use, multiple health mobile phone applications (apps) and the internet of things (a network of objects with sensors), activity trackers and telehealth equipment, and data transmission and storage.[4] Subsequently, we must consider DHT interventions as an ecosystem of their own, requiring environmentally sustainable production and recycling processes reflective of the principles of climate justice.[5] In this ecosystem, health services have an impact on environmental sustainability through their choice of DHT. Every DHT can contribute to this impact, such as telehealth and electronic medical records (EMRs), consumer use of DHT applications for health self-management, and even use of environmental health sensors monitoring air quality, for instance.[6]

Rapid growth in health data demand and digital devices add to these emissions. Health care data account for nearly 30% of the world's total data,[7] and the storage of these data in cloud servers produces a substantial carbon footprint. Here, the solution lies in green (energy- and resource-efficient) cloud computing and renewable energy technologies as key considerations for sustainable data management.[8] The digital health sector also needs to conduct

environmental audits of DHT and develop strategies to reduce the adverse environmental effects of DHT initiatives.[9,10] This requires those working within health care systems to acknowledge the contribution of DHT and services to carbon emissions. The 2021 report of the Royal Australasian College of Physicians on climate change and Australia's health care systems mentions the role of telehealth but not DHT's contributions to carbon emissions.[11]

### Digital health tools to assist adaptation to the health impacts of climate change

Critically, digital health has the potential to directly contribute to climate change adaptation and mitigation.[3,5,12] In the context of Australia, inhabitants are exposed to diverse climatic conditions, such as drought, heatwaves, floods and bushfires. Smoke-related air pollution from the 2019–20 south-eastern Australia bushfires reached hazardous levels across rural and metropolitan areas and affected neighbouring New Zealand.[13] Flooding throughout the country decimated local communities, affecting local health care systems and food security when trade routes were washed away.[14] In this situation, DHT has a role in delivering health care in difficult-to-reach settings and monitoring and mitigating localised environmental health-related impacts due to natural disasters. For example, data can be leveraged on an individual basis through apps such as AirRater, which monitors and predicts the levels of air pollution and acts as an early warning system for individuals who are most vulnerable to pollen and air pollutants.[15]

The *Riyadh declaration on digital health* reinforced the importance of digital technology, including surveillance technology, data and innovation for resilient global health care systems.[16] Digital surveillance technology is of growing importance as Australia sees the emergence of pathogens previously not endemic to the country (eg, the Japanese

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encephalitis virus), which is attributed to the impacts of climate change on vector-borne diseases.[12,17] Throughout the coronavirus disease 2019 (COVID-19) pandemic, Australian health care services adapted rapidly to virtual care models enabled by telehealth and DHT applications. They served the dual purpose of reducing carbon emissions through decreased travel and increasing the availability of general and specialist care to rural and remote communities.[11,18] These applications are environmentally adaptable to combat the escalating health impacts of climate change (Box).

## Reframing digital health for a sustainable and more equitable future

Digital health has an unparalleled opportunity to become more adaptive for climate action and resilience through a focus on sustainability, equity and the interconnection of digital health and the environment. We consider the following three enabling areas for adaptation and provide supporting examples in the Box.

### Sustainable digital infrastructure and digital health technology products

Sustainable DHT products are repairable, recyclable, biodegradable and designed to have a minimum ecological effect across their life cycle.[9] The NHS net-zero actions include digitally enabled care models and building net zero into digital maturity frameworks.[20] Ideally, this includes connectivity of digital health care systems and better enablers of digital access to care providers to minimise environmental impacts on health (eg, before, during and after disasters).

Innovation in digital health needs to shift accordingly to avoid corporate practice patterns and introduce environmentally focused design-based approaches. Environment-centred design, for instance, brings to the foreground new design thinking at the intersection of human-centred design, usability, ecology, and sustainability science.[21] The *Green guide for health care* is an example of a sustainable design toolkit integrating environmental and health care principles and practices into facility planning, design, construction, operations and maintenance.[22]

### Interconnecting digital health technology with ecological determinants of health

Human health is inextricably linked to the health of the natural environment. It is imperative we recognise ecological determinants of health, such as threats to the natural environment and health promotion of the human health co-benefits of protecting planetary health.[23] The concept of One Health integrates and unifies the approach to sustainably balance and optimise the health of people, animals and ecosystems, including the potential digital health connections across these systems.[24] To facilitate and improve interactions between One Health and digital health, there is a need to deliver near real-time data-driven contributions across systems of medicine and ecology,[25] such as the use of public-generated data in air quality monitoring[15] and algorithms that are public health-focused, which can respond to outbreak scenarios and emergency management systems.[12] The intersections of digital and environmental health literacy are equally crucial to promoting and understanding climate change adaptation.[26]

### Addressing inequity gaps

There is an unrivalled opportunity to address inequity gaps by responsibly redesigning digital health for climate change adaptation. Globally, a persistent gender gap in access to digital technologies remains; there are still 264 million fewer women than men able to access mobile internet.[27] With the COVID-19 pandemic evolving across the world, there has never been a more urgent time to deal with this issue. Furthermore, a documented link exists between climate change adaptation and the advancement of gender equity, whereby tangible action on one has a direct impact on the other.[28] Addressing the digital gender divide can empower women to directly contribute to the creation of digital climate solutions. In Australia, climate change presents an equally critical opportunity for redressing and empowering Aboriginal and Torres Strait Islander communities to lead climate action planning based on their traditional and historical knowledge of the country.[29] Furthermore, the COVID-19 pandemic has increased health care inequity for disadvantaged and marginalised people, including older people, individuals with disabilities, and ethnic minorities, highlighting the necessity to implement solutions that bridge the digital divide and adapt DHT interventions to better support these groups.[18]

This critical opportunity to develop climate resilient, adaptable DHT solutions to address the ongoing health needs of people displaced by climate change-related disasters must be seized. In Australia, this group experiences a loss of continuity of care due to a lack of an integrated EMR accessible from different health systems and geographical areas. How DHT interventions deliver when natural disasters destroy connectivity is a system vulnerability that must be addressed. The World Health Organization's guidelines on DHT interventions focusing on the inequity gap and reaching at-risk populations sustainably may be of value here.[30]

## A call for action

Climate change threats are increasing, and we must focus on adaptation and mitigation in all areas of health care. Digital health can positively contribute to climate action if implemented and maintained with environmental sustainability in mind. At the minimum, environmentally responsible digital health depends on transformation of care models and health system infrastructures to embed "green" approaches to routine practice along the continuum of design, implementation, evaluation, and consumer use.[9] DHT is inevitably one strand in a process of adaptation to climate change impacts, and this transformation lies within wider policy environment and health care contexts, which may

**Reducing digital health technology (DHT) carbon dioxide ($CO_2$) emissions to deliver equitable, environmentally sustainable health care[5,10,12]**

| Examples of DHT | Redesign considerations | Examples | Outcomes |
|---|---|---|---|
| Wearable technologies and electronic devices | • Develop eco-friendly products using sustainable design principles<br>• Choosing and sourcing sustainable, recycled and biodegradable materials and environmentally sustainable manufacturing processes<br>• Develop facilities to manage recycling or repurposing of digital devices to prolong their use | • RecycleHealth (www.recyclehealth.com) collects used activity trackers and then provides them to underserved populations[9] | • Reduction of the global impact of electronic waste through principles of circular economy and climate justice<br>• Minimisation of electronic waste toxic emissions and associated health risks<br>• Reduction of $CO_2$ emissions during the manufacturing process |
| Digital infrastructure (computer networks and computer systems powering DHTs, the emissions generated by data storage and transfer) | • Use frameworks that support health technology assessment (eg, life-cycle assessment of the technology, environmentally extended input-output analysis, and comprehensive environmental assessment) to select the most environmentally sustainable DHT infrastructure[5,10]<br>• Design data centres whose energy efficiency is driven by heat and power systems<br>• Create dashboards to monitor $CO_2$ emissions and identify processes where the $CO_2$ emissions can be further reduced[10] | • Energy star-certified energy-efficient hardware and data centres, server virtualisation, multipurpose devices (eg, products that combine printing and scanning functions) | • Consumers get a choice on DHTs assessed for environmental impacts on climate change, and toxicological impact on human health and ecosystems during the products' life cycle<br>• Health care systems can monitor their $CO_2$ emissions and develop health informatics-driven processes to reduce $CO_2$ emissions[10] |
| Electronic medical records (EMRs) | • Optimise EMR processes through health informatics principles to deliver streamlined, evidence-based care pathways, thus reducing unnecessary and clinically unbeneficial tests[5]<br>• Optimise EMR energy efficiency, and develop a digital infrastructure to support unified provision and access to a single EMR system across primary care and hospital systems[5] | • EMR processes that identify unnecessary clinical tests<br>• EMR energy efficiency driven by algorithms | • Reduction in unnecessary clinical tests translates to reduced $CO_2$ emissions and better quality of clinical care<br>• An accessible EMR system during climate change-related disasters aids in safe and optimal clinical care<br>• Improved energy efficiency |
| Telehealth | • Consider the technology infrastructure needed to deliver telehealth appointments, such as resolution, internet bandwidth, use of scroll bars[5]<br>• Optimise task flow<br>• Reduce backbone communications (ie, reduce system complexity and move to wireless communication) | • Meeting duration, internet bandwidth, type of videoconferencing equipment and choice affect the net $CO_2$ emission<br>• The higher the resolution and more complex the video conferencing system the more $CO_2$ it emits<br>• Consider when the use of phone calls is more appropriate than online or high resolution videoconferencing | • Reduction in transport-associated $CO_2$ emissions, fuel consumption, paper consumption, and personal protective equipment use<br>• Reduction in $CO_2$ emissions through choice of telehealth service<br>• Improvement in patient access to care |

Continues

**Continued**

| Examples of DHT | Redesign considerations | Examples | Outcomes |
|---|---|---|---|
| Mobile applications (apps), including SMS messaging | • Although the $CO_2$ emissions of individual mobile apps are not known, redesign needs to consider data roaming, loading graphics, screen resolution and use of scroll bars[5]<br>• Apps need to be energy efficient and data sparing<br>• Co-design apps with multiple stakeholders for optimised longer term, equitable and scalable use | • An air pollution monitoring app, AirRater, supports individuals with asthma and draws on open data monitoring of wider air quality issues (eg, traffic pollution, and alerts to bushfire smoke incidences)[15]<br>• The 1 Million Women (1MW) app helps women to adopt lifestyle modifications through self-tracking, focusing on home energy savings and clean energy options (https://www.1millionwomen.com.au/campaigns/1-million-women-app/)<br>• The Gender Climate Tracker platform and mobile app provides a global public, with regularly updated information on policies, mandates, research, decisions and actions related to gender and climate change (https://genderclimatetracker.org/) | • A timely warning system to all stakeholders of heightened risk of respiratory conditions requiring emergency management or hospital admissions[12]<br>• Reduction of inequity through design efficiency, access to open public and environmental health data, and promotion of digital health literacy |
| Augmented intelligence | • Optimise the computing infrastructure and power use towards reduced $CO_2$ emissions<br>• Perform computing in the cloud rather than on premises<br>• Train algorithms to minimise energy consumption levels<br>• Compensate for $CO_2$ emissions by using renewable energy to power augmented intelligence functions | • Augmented intelligence is used in agriculture, for prediction of renewable energy production, early disease detection, improvement of diagnosis accuracy, detection of bias | • Use of responsible augmented intelligence to reduce equity bias<br>• Reduced energy consumption and $CO_2$ emissions<br>• Optimisation of processes helping governments reach their $CO_2$ reduction targets<br>• Improved prediction of extreme weather and climate and health impact events and decision-support tools to respond more effectively<br>• Inform consumer choice on low $CO_2$ emission products |
| Internet of things | • Optimise the computing infrastructure and power utilisation to reduce $CO_2$ emissions | • Australian Governments' Smart Cities and Suburbs (https://www.infrastructure.gov.au/territories-regions-cities/cities/smart-cities-suburbs/smart-cities-plan)<br>• Used commonly in the design of smart hospitals<br>• The internet of things helps councils and industries reduce their $CO_2$ emissions and optimise energy efficiencies | • Reduction in $CO_2$ emissions at community levels through optimised infrastructure operations and processes |
| Electronic prescribing and electronic referral services | • Optimise the computing infrastructure and power utilisation towards reduced $CO_2$ emissions | • Integration of electronic referral services and electronic prescribing in health care services | • Reduction in $CO_2$ emissions through reduced paper consumption, reduced travel time, reduced fuel consumption, and use of transport services[10] |

Sustainable design is a process that seeks to reduce negative impacts on the environment, the health and wellbeing of society and economy.[19] ◆

require change or adaptation. The current gaps call for a more rigorous commitment to forms of climate justice and empowering approaches as integral to the process.[3,5] Health care professionals and consumers must be part of this transformation at every level. On an individual level, clinicians must be suitably aware and motivated to address these challenges through their own education and then educating and empowering their colleagues to create change.[31] On a system level, the key to success is in interdisciplinary approaches involving all stakeholders in expanding sustainable and impactful DHT interventions through responsible, equitable design, and in assisting health care professionals in accurately measuring and mitigating the impact of these interventions on the environment.[5,10,12]

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