What is the Carbon Footprint of Digital Healthcare?

UKERC Working Paper

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Energy SHINES was set up to facilitate partnerships between women Early Career Researchers from energy social science and humanities backgrounds and organisations in key non-energy sectors undertaking work towards net zero.

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1. Executive summary

Healthcare is changing quickly. In an increasingly digital world, the use of digital technologies within healthcare is becoming more and more common. Digital healthcare technologies (DHTs) range from electronic patient records and online appointments to the use of artificial intelligence and virtual reality.

Healthcare is also a large source of carbon emissions for every country (Health Care Without Harm, 2019). As the climate crisis worsens, we face an urgent need to reduce the amount of greenhouse gasses produced. Many nations have committed to reaching net zero carbon within the next few decades (United Nations Environment Programme, 2021). DHTs have the potential to reduce the carbon emissions associated with healthcare delivery, thereby helping countries to meet these net zero goals – for example, the use of telehealth can reduce the need for patient and clinician travel. However, digital technologies can also produce high carbon emissions. The carbon impacts of digital technologies include the emissions produced and rare minerals mined in creating hardware, the carbon cost of software development, data transfer and storage, and e-waste management after hardware is disposed of.

We urgently need to understand whether the use of a new DHT will increase or decrease the net carbon footprint of our healthcare systems. This involves complex calculations of all the sources of carbon cost of a new DHT (e.g., new hardware and software), and the sources of carbon benefit (e.g., reduced need for travel).

Once the calculations are done, we also need to ensure that the results of these calculations are communicated effectively within the healthcare system. Decision-makers need useful and actionable information about the carbon impact of a new DHT to decide whether it should be implemented or not.

DHTs offer unique opportunities to reduce the carbon impact of healthcare systems worldwide; however, quantification of the carbon costs and benefits is a complex multifaceted issue. In this report we aim to highlight key considerations for decision-making around sustainability of digital health. We cover the process of estimation, including:

- The potential of digital technologies to reduce healthcare emissions.
- A case study in how carbon benefit can be calculated from productivity improvements.
- The challenges associated with this methodology.

While our work centres on England's National Health Service (NHS), the findings are likely to be relevant to decision-makers within other healthcare systems globally that are undergoing digital transformations. Specifically, we recommend that:

- Carbon factors used by healthcare systems should be shared openly as a reference database.

- Methodology of how carbon factors are created and used should be clearly outlined and made publicly available to enable consistency in the measurement of carbon across healthcare systems.

Carbon calculations need to be done at two points – before the implementation of a new DHT, to try and reduce its carbon footprint at source, as well as after it has been implemented to check how close the estimated carbon footprint is to the actual carbon footprint.

2. Introduction

2.1 Aims and scope

This brief aims to provide insights on the carbon impacts of digital healthcare innovations to inform policy and practice in the delivery of sustainable digital interventions in health systems. It forms part of the project "Energy Social Sciences and Humanities Insights for Non-energy Sectors" (Energy SHINES), funded by the UK Energy Research Centre in 2023. This Brief is the result of a placement hosted by the Digital Net Zero team within the National Health Service (NHS) in England, and draws on a literature review and interviews with NHS experts.

2.2 What are digital healthcare technologies

The term 'Digital healthcare technologies (DHTs)' encompasses digitalisation of different facets of the healthcare system, including telehealth (delivery of health services remotely via phone or video), use of artificial intelligence, the Internet of Things (IoT), and electronic medical records (EMRs). Digitalisation has the potential to greatly improve healthcare globally, through improvements in clinical outcomes, development of personalised healthcare, and increases in efficiency in healthcare environments (Menachemi & Collum 2022).

2.3 Can they reduce healthcare's carbon footprint?

DHTs have the potential to reduce the carbon associated with healthcare. However, the potential savings need to be balanced against the cost of creating and maintaining digital infrastructure. This includes carbon costs such as hardware, data storage, the rare mineral mining required for technology, as well as e-waste management (Lokmic-Tomkins et al., 2022). Healthcare systems are estimated to produce up to 5% of global carbon emissions (Lenzen et al., 2020), which is a staggering proportion; however, total global information and communication technology (ICT) emissions are not far behind at an estimated 3.5% (Belkhir & Elmeligi, 2018). Digitalising healthcare thus clearly has the potential to end up producing more carbon emissions without proper measurement and management.

Telemedicine and telehealth have been the focus of many recent discussions about reductions in emissions from healthcare. This became particularly apparent during the Sars-Cov-2 pandemic that forced the adoption of telemedicine and virtual appointments at a rapid rate in many countries (Gunasekeran, Tseng, Tham & Wong, 2021). Current literature suggests that the adoption of telemedicine leads to net carbon savings per consultation, predominantly through a reduction in travel associated with each appointment within the UK healthcare system (Purohit et al., 2021), although the authors note that the savings in carbon are highly variable and context specific (for example, more specialised services tend to cover a wider geographic region and therefore lead to a greater reduction in travel-based carbon by offering telehealth appointments).

The advances in artificial intelligence (AI) technology have led to speculation on how AI could be used for healthcare. One study recently estimated an 80% reduction in greenhouse gas emissions if autonomous AI systems replaced a diabetic eye exam usually conducted by an ophthalmologist in the United States (Wolf et al., 2022 – of note, the authors did not include the greenhouse gas cost of the appointments leading up to the exam, or the cost of creating and training the AI system in their calculations). A recent narrative review into the potential uses of AI in reducing the carbon footprint of healthcare highlighted multiple potential areas of exploration, such as improving maintenance, optimising supply chains and operational activities, and reducing energy consumption (Das & Chandra, 2023). Notably, this review drew on studies and reports from the American Medical Informatics Association, the World Health Organisation, and the NHS, demonstrating the international demand to decrease the carbon associated with healthcare.

However, digital healthcare also comes at a significant carbon cost. Globally, the information technology sector consumes vast amounts of energy, and data usage is currently growing at an exponential rate (Tongue, 2019). When taking into account measures like telehealth and AI usage, we must weigh the potential benefits of reduced travel and carbon emissions with the emissions produced by the ICT infrastructure needed to maintain these services, and in the case of AI the emission costs of development and training the algorithms required.

2.4 How do we measure carbon?

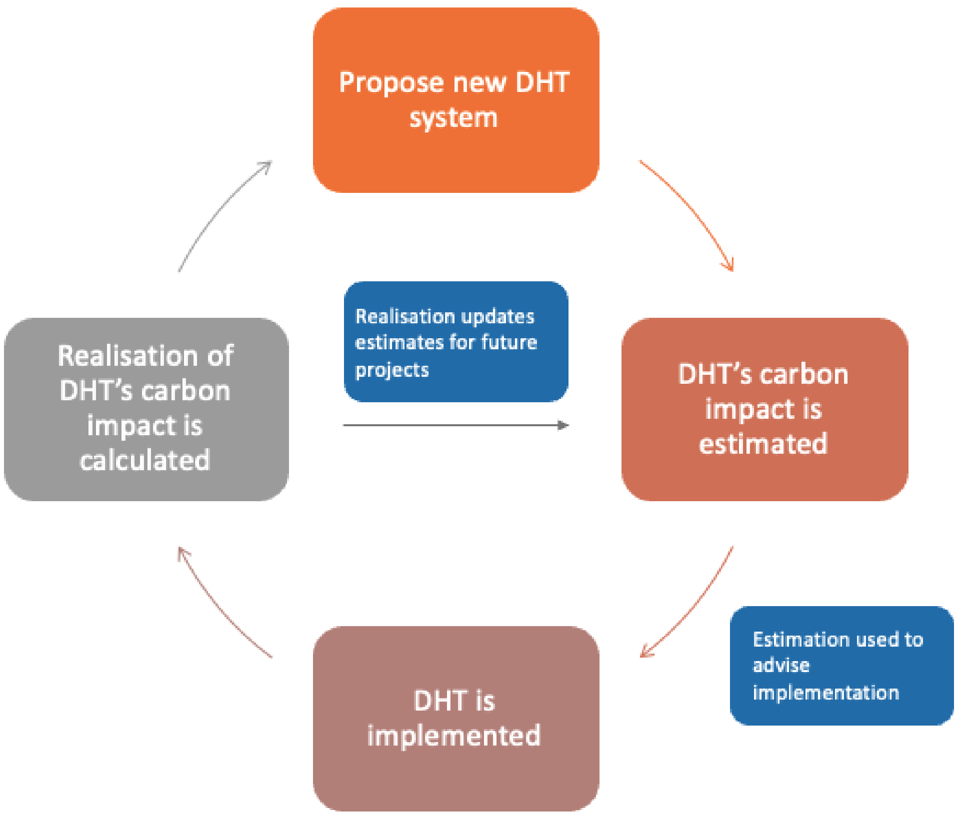
Given that there is evidence both of carbon cost and carbon benefit of DHTs, there is clearly a pressing need to create measures of carbon emissions from digital transformations that are accurate and informative. How we create these measures will be key to understanding whether new digital transformations within healthcare systems are in line with goals to reach net zero.

Currently, estimations of the carbon cost are conducted using carbon factors, or emission factors (we use ‘carbon factors’ here). These estimate the average emissions of a given source – for example, the estimated carbon produced in creation of a piece of hardware, or the carbon cost of server storage. Many large datasets are available to use to create carbon factors on a variety of different products and services – for example, the Sustainable Healthcare Coalition provides estimates of the carbon factors by a variety of healthcare services within the NHS (Sustainable Healthcare Coalition, 2015). When new DHTs are proposed (for example, roll-out of a new electronic medical record system, or adoption of a new smartphone app for patients), calculation of the carbon cost of the implementation involves the estimation of a variety of factors – for example, the hardware and cloud computing costs of the new digitisation, the cost of algorithm development, data storage, etc.

To best understand the carbon impact of a new DHT, there needs to be an effective *estimation* before the technology is adopted within the healthcare system, and a *realisation* period after the adoption to assess whether the estimated carbon impact is comparable to the actual carbon impact.

The estimation of the emissions cost of a new digitalisation intervention also requires a high level of stakeholder involvement. For example, NHS England is developing a procedure for assessing carbon impacts as part of their existing business case application process, which applies to any new service. If a new DHT is proposed as a business case application, the applicant needs to be sufficiently motivated to engage with calculation of the carbon impact. This will include estimating the number of hardware/devices that need to be purchased, estimating the time and cost of the development of algorithms, the amount of data that will need to be securely stored, among many other factors. Ensuring that the applicant is sufficiently motivated and understands the importance of the emissions calculations is key.

Figure 1: Estimation and realisation in a simplified DHT proposal system



Estimation occurring before the implementation of a new DHT allows for the sustainability departments of healthcare systems to estimate whether it is in line with the system's sustainability goals, and to propose changes to the implementation that could reduce carbon (Figure 1). For example, utilising cloud computing or using refurbished as opposed to new hardware can lead to significant carbon savings.

Post-implementation realisation measurement can highlight differences in the estimated and actual carbon footprint of the DHT. For example, if a DHT business case estimated that it required 100 terabytes (TB) of storage, but after implementation it was found to use 150TB, that difference would be essential in calculating the carbon emissions generated by the digitisation. Equally, if they estimated using 500 new pieces of hardware but only required 400, the saving would be considerable. The discrepancies can then be used by the healthcare systems to update future estimations for new DHTs.

There is a self-evident need to create accurate carbon calculations in the digital healthcare space. However, the measurement of these factors should be seen as an iterative and ongoing process, involving both estimation and realisation calculations and comparisons.

2.5 Communication and involvement in the digital healthcare space

The final, but perhaps most crucial, stage of calculating the emissions impact of DHTs is ensuring that the calculations have sufficient impact. The primary goal of a healthcare service should be to improve patient outcomes. However, there is an array of other competing issues that need to be considered – such as the cost of delivering healthcare, the conditions and wellbeing of the staff, and the wider societal impact. Decarbonisation should be considered as prominently as these other factors; however, emissions-related issues are often given less weight due to their lack of perceived immediacy. It should be stressed that climate change is a public health emergency, and therefore by failing to meet their decarbonisation goals, healthcare services are laying the groundwork for increased pressure on their services in the future (Health Care Without Harm, 2019).

Communicating the results of calculations of carbon impact can be difficult, considering that pure numbers tend to be relatively meaningless for many decision-makers. To improve the impact, more easily understandable methods should be considered – such as using a red-amber-green (RAG) rating system that indicates how new digitisations would align with net zero goals, or cut-off criteria that can be communicated directly to decision-makers when digital transformations are proposed. Understanding how the calculations are communicated and used within healthcare systems is as important as ensuring that the calculations are as accurate as they can be.

In the next section, we highlight one area of carbon calculation that has not previously been addressed in health sustainability studies: productivity impacts of DHTs. This is an area where Social Sciences and Humanities (SSH) offer useful approaches, understanding the impacts of digital technologies not just in terms of carbon embedded in hardware, but also in terms of wider impacts on employment, patient care, and safety.

3. Case study: can productivity improvements lead to carbon savings?

DHTs often highlight productivity improvements as a benefit. Here we examine the methods required to estimate potential carbon savings from improvements in productivity within a digital healthcare setting. This case study focuses on the NHS in England.

3.1 Carbon benefit

While the carbon cost of digitisation initiatives has a clear method for estimation, it is often much more complex to estimate the carbon *benefit* of a new DHT. Improvements tend to be more nebulous and less easily quantifiable than cost (as with productivity improvements). Some of these aspects are easier to quantify than others – for example, a digitally enabled stock management system can lead to reductions in waste produced by unused stock, which can easily be quantified by individual healthcare providers, and reductions in travel can be easily measured too. However, to gain an accurate overview of the carbon impact of a DHT, we need to address even the hard-to-quantify benefits, such as improvements in patient experience and increased clinical time spent with patients.

The process of quantifying the carbon benefit of productivity improvement requires identifying productivity improvements that will have knock-on effects for carbon emissions. In addition, further research is required to examine how other aspects of digital transformation could lead to carbon costs or savings. Below we detail a case study in trying to identify how to calculate carbon benefit from productivity metrics in digital healthcare.

3.2 The problem with productivity

Productivity benefits can be measured in a variety of ways, with the ratio of input (labour and capital) to output. The input measure of healthcare systems can be seen as spending on healthcare related goods and services. In the UK, our current output metric is the quantity of healthcare delivered adjusted for changes in quality of care (Charlesworth, 2019). Currently, there is no standard measure of productivity used across all healthcare systems.

The NHS Digital Benefits team recently released a standardised measure of productivity specifically focussed on digital transformations within NHS England. This aimed to cover traditional, cash-releasing productivity measures, as well as qualitative metrics that have been historically underemphasised. This step towards standardisation is key not only in the measurement of productivity, but in the measurement of any carbon benefit associated with improved productivity.

Table 1: Subset of the digital productivity metrics for the NHS

Metric	Description
Hours saved (hours/£)	Employee hours may be saved as a result of implementation of a new tool. This could be cash-releasing resulting in lower resource use (£) or non-cash-releasing resulting in hours redeployed.
Number of full-time equivalent (FTE) staff redeployed	The implementation of a technology may result in staff no longer being needed in certain roles (e.g. administrative staff replaced by a digital worker).
Number of adverse safety events; Significant Incidents[1] (SIs); and/or data breaches	Higher levels of productivity have been evidenced to support improvements in safety.
Staff-to-patient ratio	Evidence suggests that a small staff-to-patient ratio leads to improvements in patient outcomes, efficiency, and length of stay for patients – linked to patient experience, adverse safety events, and hours saved to redeploy staff.
Clinical time spent with patients	Removing administrative needs for clinical staff can allow for these staff to reinvest time into patient-level care.

3.3 Can we measure productivity-related carbon savings?

The specific focus here will be on productivity measures that allow for increased reallocations of staff hours, and on metrics that can lead to improvements in patient care.

The first avenue of investigation for this project was to examine whether a carbon factor could be created for one employee. This would require a carbon factor covering average travel, office space usage, hardware, software, and data storage per worker. This can be utilised to estimate the carbon saving related to staff hours that can be reallocated, or staff that can be redeployed due to improved productivity; fewer staff required for a specific team or project leads to a carbon saving. This could also be applied within settings where there is a high reliance on bank or agency staff workers; where full-time staff could be redeployed to fill these roles, a reduction in the number of bank staff would lead to a carbon saving (because the

[1] Serious incidents are events in health care where the potential for learning is so great, or the consequences to patients, families and carers, staff or organisations are so significant, that they warrant using additional resources to mount a comprehensive response; for example, an avoidable death. See: https://www.england.nhs.uk/wp-content/uploads/2020/08/Serious_Incident_framework_NHS_England_.pdf

overall number of staff would be reduced). However, this is clearly a very specific calculation that would vary widely depending on the hospital or healthcare provider that the digitisation was affecting, and may best be calculated *after* the implementation of the digital transformation instead of an estimate being produced beforehand.

For our second focus, we can draw on previous research examining carbon savings associated with improvements in patient care. The specific metrics outlined by the Digital Productivity Team here are staff-to-patient ratio as well as serious incidents and adverse events. Previous research demonstrates a link between both factors and the length of time that patients are hospitalised. The UK already has existing carbon factors for the length of stay of a patient in hospital, making this a useful metric that can leverage already available data. Length of stay is often measured in terms of 'bed days': one bed day means one patient staying in a hospital bed for one day.

Staff-to-patient ratio has been previously researched, specifically nurse-to-patient ratio, with studies indicating that the fewer patients there are per nurse, the better the patient outcomes will be (Dall'Ora et al., 2022). This has been quantified in terms of bed days, with several studies showing that an improved staff-to-patient ratio leads to a reduced number of bed days per patient (Griffiths et al., 2018; Lasater et al., 2021). Therefore, if a new digital transformation had the potential to improve the nurse-to-patient ratio within a specific healthcare setting, there could be an estimated decrease in the number of bed days per patient associated with it. Identifying a specific number of fewer bed days from improvement in nurse-to-patient ratio would be a first step in creating a carbon factor that explicitly relates to this productivity improvement.

Patient care can also be impacted by avoidable harm. A wide variety of harms can be caused to patients when they are under the care of the health service, and avoidable harm accounts for a large proportion of overall bed days in a healthcare system (World Health Organisation, 2021). Therefore, if a new digital transformation can reduce the amount of avoidable harm that occurs within a healthcare setting, this can also reduce the amount of carbon associated with patient care through a reduction in bed days. The measurement of this will require the synthesis of previous studies across the range of avoidable harm events to identify the estimated harm to patients and the increased length of stay associated with each, and then an averaging across these different factors to create a usable 'patient harm' carbon factor.

3.4 Challenges

The key challenge of the calculation of productivity-based carbon factors is the lack of certainty on both sides of the equation. Measurements of productivity can be unreliable, and tend to lack standardisation, which can make any carbon factors associated with them equally unreliable. In addition, carbon factors are often based on large generalisations – for example, if creating a carbon factor for avoidable patient harm, a large variety of causes of patient harm would need to be averaged to create a single number. However, a single number is more useable than a specific number – it is easier to apply a carbon factor for general patient harm than specific factors for incorrect medication prescription, falls in hospitals, and accidents in surgical procedures. These kinds of generalisation are necessary to create carbon factors that can be useful, but can lead to greater inaccuracies in carbon measurements.

The most reliable way to ensure that the measures used are as accurate as possible is to ensure that measurement is iterative. The proposed productivity measures for a new business case should be carefully measured after the digital transformation has been implemented, as should the carbon factors associated with them. This applies to incidents of patient harm, hours saved and staff reallocated; if there is a large deviation from the proposed benefits and the actual benefits, this also has knock-on effects for carbon emissions that can be estimated from these metrics. Knowing how much the estimations deviate from the reality also allows for future updating of calculations for equivalent business case applications.

It is also important to note that carbon factors relate to a specific unit, whether this is an hour of staff employment, or a patient's hospital stay, or any other measure. Caution is required when making assumptions about how these units themselves may change – in particular, due to unmet demand for health services. There is a chance that any productivity gains will result in increased delivery of healthcare services. So, while carbon savings are achieved relative to health outcomes, absolute carbon savings might not be achieved.

For example, if the duration of a patient's stay is halved, this represents a halving of carbon emissions associated with that stay. However, if another patient then occupies the freed-up bed, and twice the number of patients are treated in the year, the carbon emitted annually will be the same. Similarly, if an employee's annual hours are halved, this is a halving of carbon associated with that employee. However, if their freed-up time is allocated to other tasks, and they carry out double the tasks in the year, the carbon emitted annually will be the same.

In practice, it is not realistic for all carbon calculations to use absolute metrics, due to uncertainties and complexities (such as the amount of latent demand), and most estimates therefore focus on carbon *intensity* of a specific healthcare event. However, it is vital for carbon calculations to be transparent in their metrics and assumptions, so as not to confuse relative and absolute measures, or foster unrealistic expectations of carbon reduction. This also reinforces the necessity of post-implementation evaluation, to check the actual real-world impacts of DHTs.

4. Conclusions and recommendations

This Brief has aimed to provide insights into the challenges and opportunities for assessing the carbon impacts of digital health innovations. The digital transformation of healthcare systems around the world is an ongoing process that promises many benefits, one of which could be a reduction in healthcare-associated carbon. However, digital technologies can be incredibly carbon-intensive to produce, run, and dispose of. To make sure that digital healthcare technologies (DHTs) are compatible with net zero goals, we need accurate ways to measure the carbon impact of DHTs as they are proposed and implemented.

Currently, our methods of estimating carbon impact involve producing carbon factors for different aspects of DHT delivery – such as those for transport, hardware, etc. The process of creating carbon factors is complicated, specifically around carbon benefit. To ensure that we are consistently measuring the carbon impact of a DHT to the best of our abilities, the carbon calculations should be done at two points – comprising of an estimation before the implementation of a DHT, and a realisation calculation afterwards. This allows for the post-implementation realisation calculations to be used iteratively to update the estimations before DHTs are implemented. All the carbon factors used within the calculations should also be updated frequently as more data becomes available.

Recommendations

- Carbon factors used by healthcare systems should be shared openly as a reference database. This would allow for transparent and reproducible methods of estimating the carbon impacts of healthcare systems across the world, and allow greater comparability between countries.
- Methodology of how carbon factors are created and used should be clearly outlined and made publicly available to enable consistency in the measurement of carbon across healthcare systems. Currently the process of measurement is decided within individual healthcare systems and could vary drastically between countries and healthcare providers. Sharing methodology would also enable greater collaborative efforts to accurately measure and reduce carbon worldwide.
- Digital transformations should involve *estimation* when a new initiative is proposed, as well as post-implementation *realisation* measures to identify deviations from original estimates. Currently within NHS England, the measurement occurs as estimation but not at realisation. Understanding that DHT implementation is a process that can incorporate carbon reductions throughout its lifecycle is critical to reducing the carbon footprint of healthcare, and the process of iterating and updating the measurements can improve the accuracy of future estimations.

To meet these recommendations, further involvement from SSH researchers will be invaluable. SSH researchers can help understand the systemic implications of digital transformation and innovation, and examine its effects on the healthcare system as a whole – taking into account factors mentioned above, like employee hours and patient safety. In addition, SSH can be used to communicate the findings of this research in an effective manner to promote sharing of research methodology and changes in policy in line with the results of carbon measurement.

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