Environmental sustainability and biobanking: a pilot study of the field

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Biobanks have expanded dramatically over the past few decades, as have their storage and computational requirements. These requirements have environmental impacts, including mineral extraction and manufacturing processes associated with digital infrastructures, carbon emissions related to sample storage and data storage and analysis, and associated waste. Here we analyse whether biobanks have any specific policies about these environmental impacts. We also explore the ethical assumptions associated with how people with a professional stake in these discussions - those researchers using biobank resources, digital sustainability experts – think about these issues, and the implications embedded within them. Biobanks we spoke to had no specific relevant policies and researchers reported little awareness of issues. When researchers did discuss the issues, they often drew on consequentialist narratives and/or appealing to worse problems. Some researchers and digital sustainability experts suggested approaches to improving existing and future biobanking practices, though not in a standardised way.

Keywords: biobank; biobanking; sustainability; environmental impact; cost–benefit

Introduction

Biobanks increasingly support a wide range of health research (Rush et al. 2020), and promise to accelerate our understanding of the complex relationship between genes and the environment in the development of disease, as well as improve...
global healthcare treatment and services (Chalmers et al. 2016; Caulfield, Borry, and Gottweis 2014). Biobanks advantage researchers by enabling access to a wide range of heterogenous samples and data, as well as saving them time and funds on the collection, storage and curation of such resources. Furthermore, combining large-scale data sets promises to answer research questions of both national and global significance (Chalmers et al. 2016). The ability to allow a multitude of researchers access to a resource means that biobanks are viewed as a key public benefit and are often funded publicly (Chalmers et al. 2016). Large-scale biobanks exist in a number of countries, with some of the largest in the world being based in Europe (e.g. UK Biobank, Biobank Graz, Austria, The Estonian Biobank), North America (“All of us”; “CanParth”), and Asia (Biobank Japan, The Taiwan Biobank, Shanghai biobank) (Zohouri and Ghaderi 2020). New large-scale biobanking initiatives and consortia continue to emerge in Africa (54gene (54gene), H3Africa (H3Africa)), in Europe (with 21 countries signing a declaration to share data on at least 1 million human genomes transnationally by 2022 (Saunders et al. 2019)), and Asia (GenomeAsia100K (Genome Asia 100K)).

At the same time, biobanks have an environmental impact. This comes from the materials used during the sample/tissue storage processes, as well as the energy required to run the biobank. For example, low temperature storage freezers required to house biosamples need a significant amount of energy to operate (the lower the temperature the more energy required). The energy consumption of an ultra-low freezer can equate to that of an average UK household (Chatterton et al. 2016). These freezers need to be housed in temperature-controlled rooms, which in turn require energy. A 2014 internal survey of a UK university reported that the institution had over 500 ultra-low freezers, plus several thousand further non-ultra-low freezers and fridges (personal communication). Furthermore, freezers need to be replaced every decade or so to ensure efficiency, and old freezers require waste disposal. The embodied carbon emissions of ultra-low freezers (carbon emissions associated with extraction of materials, manufacture and transport) are currently unknown, though in some sectors embodied emissions can reach as high as 70% of the overall life cycle emissions (Lannelongue 2022).

The databases, data infrastructures, and AI-assisted software that support data analysis of biobank resources also have environmental impacts (Whitehead et al. 2014). These include heavy carbon dioxide emissions linked to the energy required to generate and process large amounts of data (Freitag et al. 2021); the impact on the material environment (e.g. where data centers are constructed, including how local biodiversity and the local environment, e.g. water consumption is affected); the use of unsustainable practices for extracting minerals for technological components; the manufacturing processes associated with digital infrastructures; and the e-waste from their disposal (Lepawsky 2018; Gabrys 2012). The amount that biobank related activities contribute to these emissions and practices is unknown, though a recent article suggested that a genome wide association study from one biobank for one trait could be equivalent to driving
100 km in a car (Grealey et al. 2021). Other analyses, for example, RNA sequencing, are considerably more energy intensive (Grealey et al. 2021).

Just as there is an ethical obligation for other areas of the health sector to consider their negative environmental impacts (also called their environmental sustainability) (Lenzen et al. 2020; Macpherson and Hill 2017; Tongue 2019), biobanks should also consider these issues (Samuel, Lucivero, and Lucassen 2022). This, however, involves a range of considerations, including an ability to measure biobanking’s environmental impacts (carbon emissions associated with different storage and analysis practices; biobanking’s contribution to mineral extraction and effects on biodiversity; water consumption in terms of the materials that it uses etc), and the need to ethically balance these with other ethical factors (e.g. addressing benefits to health; issues of participant/patient autonomy, privacy issues etc) (Samuel, Lucivero, and Lucassen 2022). To date, these considerations have received little attention and we have little understanding of what the exact environmental impacts of biobanking are; how they can be assessed; and by which metrics and standards to use. The extent to which biobanks and/or those who use biobank resources are considering these issues in their research is also unknown. This is not helped by the fact that the concept of environmental sustainability is defined in a multitude of ways, with meanings that are neither stable nor fixed, and that are nebulous and multiple (Dobson 1998).

As a first step to addressing some of these considerations, we wanted to provide some preliminary empirical data about how people with a professional stake in these discussions – biobanks, those researchers using biobank resources and sustainability experts – perceive these issues. The theoretical underpinning of this work is responsible innovation, whereby the understanding, knowledge and views of stakeholders around specific issues are established so that they can help inform policy (Stilgoe, Owen, and Macnaghten 2013). We considered (a) do biobanks have any policies specifically pertaining to environmental sustainability, and if so, how do they apply meaning to them? (b) What awareness about the environmental impacts of biobanks do health researchers whom biobanks support have? And (c) how do health researchers and digital sustainability sector experts apply meaning to the environmental impacts of biobanks and reflect about these ethical issues?

We draw on three qualitative studies, each of which was part of a larger project exploring the ethical issues associated with biobanking. First, we asked 20 European population-based biobanks about whether they had specific policies pertaining to environmental sustainability and what they were. Second, as part of interviews with 10 health researchers using the UK Biobank resource that asked broader questions about the ethics of biobanking,5 we asked the interviewees about their awareness and views on the debates surrounding the environmental sustainability of biobanking. Third, we complemented these findings with another interview study that explored the perceived issues and challenges of those working in the sustainable digitalisation sector, during a sub-set of which,
the health research sectors’ role associated with digital environmental sustainability issues were discussed.

Methods

**Biobank policies on sustainability: data collection**

This was part of a wider project exploring policies associated with biobanks in Europe, the methodology for which has been described elsewhere (*forthcoming*) (2022). In brief, 47 European-based biobanks⁶ were approached via email to ask for information on a range of policies and documents, including any policies pertaining to sustainability (including environmental sustainability e.g. the environmental impact of biobanks). Websites of these biobanks (if in English, Dutch or German) were also checked. 21 national BBMRI nodes were also invited (BBMRI-ERIC), by email, to distribute our invitation email to biobanks within their own jurisdictions. After a comprehensive website search and two follow up emails to non-responders, in total, we had complete information about 20 biobanks.⁷ Analysis of data was limited and binary (have/do not have policies, including whether they were aware of any broader policies associated with their host institution).

**Researcher interviews**

A list of successful applications to access the UK Biobank resource was sourced from the UK Biobank website (n = 502). Principle investigator researchers based in the UK, and who had publicly accessible contact details (n = 106), were invited to take part in the interviews via email in Spring 2021. Following a reminder email, 10 researchers agreed to participate, and interviews were conducted via Microsoft Teams by the end of August 2021. All interviewees were based in the UK. Interviewees were from diverse disciplines including neuroscience/psychology (n = 2), pharmacogenetics/pharmacology (n = 2), epidemiology (n = 2), medicine (n = 2), optometry (n = 1) and public health (n = 1). During interviews, participants were asked about their understanding of the debates surrounding the environmental impacts of biobanks and whether they had any reflections on this understanding. Researchers did not prompt interviewees about these environmental impacts unless they were specifically asked, in which case the researcher noted very briefly that these environmental impacts could include aspects associated with, for example, carbon dioxide emissions associated with freezers or digital infrastructures. Inductive thematic analysis of this aspect of the interview data was conducted by both GS and FH in line with the approach described by (Braun and Clarke 2021). Independently, GS and FH familiarised themselves with the interview transcripts by carefully reading and re-reading the transcripts. Transcripts were then inductively coded independently using NVivo software.
Independent codes were discussed between GS and FH and overlaps emerged. Overlaps were discussed in several further meetings to develop broader themes.

**Sustainable digitalisation stakeholder interviews**

Interview recruitment and analysis has been reported elsewhere (Samuel, Lucivero, and Somavilla 2022). In brief, interviewees were identified via bibliometric analysis and snowballing. Seventy-three stakeholders were contacted, and 24 interviews were conducted virtually, including with academic researchers (computer science, engineering, social science), NGOs, advocates, as well as those working in policy, industry and data centers. Interviews lasted between 32–92 mins (most being between 50–70 min). The aspect of interviews relevant for this paper included discussions with seven interviewees about how environmental sustainability issues were relevant to the biobanking and health research sector. These interviewees were based in the UK (n = 3), the EU (n = 2), Australia (n = 1), and the United States (n = 1). They included a consulting engineer (n = 1), industry representative or executive (n = 2) academic (n = 2; sustainability and computing systems; computer scientist); scientific lead at data center (n = 1); and standard bearer representative (n = 1). Analysis of this interview data was conducted by both GS and FH using a thematic analysis approach described by (Braun and Clarke 2021) and reported above. Independently, relevant aspects of the interview transcripts were carefully read for relevant ideas. Coding was discussed between GS and FH to develop broader themes.

**Limitations**

Some biobanks were part of wider institutions that may have encapsulating environmental sustainability policies, but for various reasons (including the delegation of responsibilities within larger institutions) biobanks may not have been aware of them. Furthermore, only 20 biobanks were asked about their policies pertaining to sustainability whilst many more biobanks exist - however, responders were mainly resource-intensive biobanks, and those most likely to have relevant policies. Finally, this was a preliminary analysis, and during the interviews the question of environmental sustainability was among other questions that were explored with both health researchers and sustainable digitalisation sector stakeholders. This research could be followed by in-depth interviews about this subject in the future. This further research should ensure that a wider range of biobanks and researchers are considered, including those from low-to-middle income countries.

**Findings**

Our findings are divided into three sections. First, we report on how the biobanks and health researchers we spoke to had little awareness and had not engaged with
issues of environmental sustainability in any relevant way. Second, we describe how many health researcher interviewees and some sustainable digitalisation sector interviewees had hesitation towards the health sector needing to have any real engagement with environmental sustainability issues. Finally, we describe how some health researchers and a number of sustainable digitalisation sector interviewees were frustrated with these views, and suggested practical approaches to addressing the environmental impacts of the sector, while concomitantly questioning the usefulness of their own suggestions.

Little engagement with issues of environmental sustainability

When biobanks were asked if they had any policies on sustainability, no specific policies were mentioned bar when sustainability was considered as part of the broader organisation within which some biobanks were housed, or when it related to sustainability initiatives that were more associated with the “economic sustainability” of biobanks (Samuel, Lucivero, and Lucassen 2022) – an issue that is becoming increasingly prominent in the biobanking sector and literature (Watson et al. 2014). There were only two biobanks that engaged with the concept of environmental sustainability. First, one biobank’s website contained a statement that they “are aware of the impact of our [their] activities on the environment and strive at saving materials and energy” (translated by the biobank for the authors). A representative of this biobank explained how beyond this generic statement, energy consumption is seen as an important parameter when ordering freezers, as well as more broadly. Furthermore, while unaware of the discussions associated with sustainable digitalisation, they were open to being informed about the negative impacts associated with the use of databases and associated digital technologies. The second biobank took a slightly different stance on environmental sustainability. For them, because biobanking was considered as having fewer negative environmental impacts than the alternative i.e. gathering data for one specific purpose at one specific time, there was less reason to worry about this issue. However, they did emphasize the importance of data re-use as a key aspect of environment sustainability.

Similar to this, health researcher interviewees had little awareness of any debates considering the environmental impacts of biobanking: “I haven’t come across any of those debates [about environmental sustainability]” (interviewee 5); “I hadn’t thought about it” (interviewee 8). Many researchers were therefore unable to apply meaning to the term and asked the interviewer what they meant by environmental sustainability (interviewees 5, 7) - “in terms of what?” (interviewee 1) and “in what sense?” (interviewee 6). Some interviewees, while not considering the issue in depth, had considered environmental sustainability more generally - even if it was outside of their professional role. Interviewee 2 explained how they applied meaning to the environmental impacts of the digital sector:
I haven’t heard about the debate, but I have thought about that myself, about all these clouds that people think are just clouds, but they are obviously not, they are horribly big machines standing somewhere, and obviously having an important impact on the environment because of the cooling that they need, the energy that they demand, etc., etc., yes, I’m aware of that.

When researchers did reflect on the environmental impacts of biobanking more generally, responses could be categorised into two ethical positionings: a consequentialist positioning whereby they drew on an ethical (not economic) cost–benefit analysis lens to emphasise that the potential benefits of health research far outweighed the environmental impacts; and by appealing to worse problems.

**Consequentialist positioning**

Despite, or perhaps because of health researcher interviewees’ low level of awareness associated with the negative environmental impacts of biobanking and the research it supports, more than half of health researcher interviewees expressed little concern for environmental sustainability issues. Many of these interviewees framed their moral positioning – either implicitly or explicitly – by drawing on consequentialist reasoning, and specifically, through a cost–benefit trade-off lens. In these responses, environmental impact was perceived as the “cost”, which sat against benefit: “with everything in life, there’s a balance between the cost, the real cost, the environmental cost, the cost to whatever, versus the potential benefit” (researcher 7). There was little conceptual clarity about what the environmental costs were. Benefits were articulated in terms of both health research (“the benefits of having a resource. .[is]. .that [it] is available for everyone [for research]” (researcher 8)), and health outcomes. Responses were often built upon the assumption (or even a moral imperative) that collecting and analysing ever larger amounts of data will lead to health research that can advance science and lead to health benefits for all:

we cannot stop combining data and needing more powerful and bigger historic systems to actually accumulate all the data that we are obtaining and being able to process it quickly and fast and reliably, so we cannot stop doing that because that’s the way in which we actually can advance in our knowledge that has an important impact on well-being as well (researcher 2).

These findings can perhaps be seen in the context of UK Biobank being a key resource for UK data-driven health research: many of the health researchers had accessed a wide range of data from UK Biobank, including self-reported data (e.g. demographic and socioeconomic data, as well as data on lifestyles, behaviors, and medical conditions), biomarkers and genomics data, and clinical and hospital data. Many of the researchers appreciated the scale and statistical power that the UK Biobank data enabled, which made the resource unique and irreplaceable for them. In fact, when adopting a consequentialist positioning, many interviewees stressed the importance of including ethical calculations on the already positive
influence biobanks had on environmental sustainability compared to the alternative worse non-biobanking methods that superseded these ventures. For these interviewees this positive influence needed to be considered within any moral judgment in terms of canceling out the negative environmental impacts:

the carbon footprint is miniscule if you consider the fact that you’d probably have to do the studies in different patient groups, have to recruit them, and all that process of somebody travelling from one place to another to be recruited, or researchers traveling from one place to another to be recruited, etc (researcher 1).

If researchers were trying to do this independently in smaller labs, would that have a smaller carbon footprint? I doubt it very much. In my case, for instance, so there was some carbon footprint generated through collecting those brain scans, but imagine if everybody went out to try and collect that sort of amount of data and collected that many scans, then the carbon footprint would be many, many higher orders of magnitude. So the fact that, that data, once it’s been collected can be reused numerous times is absolutely brilliant (researcher 6).

Finally, one health researcher, interviewee 9 from the digital sector (who was the scientific lead at a data center) explained how building public trust in biobanks and health data research was also necessary (since it was sometimes lacking9), and to do this required the development of digital security systems that themselves have a significant environmental cost. The cost–benefit value judgments then need to also incorporate benefits attached to public trust in health data research:

you’ve got other things, haven’t you? You’ve got trust. I mean again, so there’s information stored on individuals … and when you bring trust, digital trust … you bring in the security in a digital sense as well … all of these things cost more energy (researcher 9).

**Appealing to worse problems**

About half of the interviewees (also) ethically positioned themselves as appealing to worse problems to downplay the concerns about the environmental impact of biobanks. To do this, they compared the perceived environmental impacts of biobanking and the research it supports to the perceived higher impact from other sectors (researchers 1, 3, 7). For example, researcher interviewee 3 noted:

compared to many other environmental impacts, I would imagine that’s [biobanking is] a fairly minor one. Maybe, personally, it’s not something that I worry about compared to other sustainability or environmental impacts. To the best of my knowledge, the scale is not too great.

In the extract below, interviewee 7 reflected on the environmental impact of leaving freezer doors open in supermarkets as a more pertinent place than the health sector to focus attention to reduce negative environmental impacts:
I think we use a lot of freezers for other things that perhaps we could do a bit more efficiently, like shut the doors of the freezers in supermarkets, so that you don’t chill the whole building. There are a lot of other things we could improve on that wouldn’t affect our ability to find new diseases and treatments.

Similarly, interviewee 10 compared their perceptions about the energy use associated with health/biobanking sector to that associated with the use of cryptocurrencies. For them, health research for the “benefit of mankind” was considered a better use of energy than the less valuable use of energy for blockchain technologies, and that effort should be directed to addressing the latter:

as long as blockchain exists, I don’t think you can really complain. [...] spending it on super-computing facilities to store human data for the benefit of mankind is probably one of the better things you could use the energy for rather than supporting cryptocurrencies, or whatever (researcher 10).

Finally, sustainable digitalisation interviewee 2 compared the perceived value of health research to video streaming to highlight how the latter is a worse problem than the former: “... at least that’s [health research has] got a purpose. [...] at least it’s better”.

Furthermore, a couple of researchers who took this ethical stance viewed the causes underlying the environmental impacts of data storage and analysis as coming from the digital sector and that these causes were “part of the wider debate” (researcher 5), such that the “specific” (researcher 5) impact from biobanking was too little to require intervention. These interviewees deferred any concerns associated with the environmental impacts of biobanking-related data storage and analysis to the digital sector because they believed that any impacts would be managed elsewhere: “I’m sure it will become more efficient, but yes, no, that’s not something that concerns me, no” (researcher 4).

In contrast, a number of interviewees from the sustainable digitalisation sector were frustrated that health researchers drew on such arguments. For these interviewees, it was problematic for non-digital sectors to consider themselves to have what they termed “a free pass” (interviewee 10) to not think about their digitally-associated negative environmental impact. Sustainable digitalisation industry group representative interviewee 20 remarked:

health gets a free pass, right, because it’s health ... [. .]. Yeah. [sarcastically]. Steel should get a free pass because we’re building people’s homes. It’s the same. Look, I’ve had this with wind park people. “We are making the energy transition happen. We are free of any sustainability,” and I’m like, “But you made the blades out of non-recyclable plastic. Really? So, in 20 years when these wind parks are not operating anymore, what do we do with the blades? Did you think about it?” “Yeah, but we’re, we’re making the energy transition happen.” “Yeah, but you’ve still got to recycle the blades man”.

Sustainable digitalisation interviewee 15 who owned a company in the sustainable digitalisation sector concurred. This interviewee described how all sectors should
take responsibility for their environmental impacts, including those that have a perceived positive impact on society: “‘I’m enabling the next research in cancer,’ or whatever it is. Or, ‘I’m enabling blah de blah,’ right. ‘I’m doing something in education.’ It’s like, ‘Okay, but we have a responsibility to look at all sides’”. Sustainable digitalisation interviewee 8, who was a researcher in sustainability and computing, explained how environmental sustainability questions should be at the forefront at the outset of research projects, and throughout the process, even if it transpires that any environmental impacts are minimal; the need to assess is important to better understand attributed responsibilities:

people should be thinking about how much extra data will it use, and therefore how much more equipment will we need to get because of that? That’s, that’s certainly a valid question, but you might find the answer is, “actually, it’s not a problem”, but you need to ask the question.

At the same time, as we go on to show, there was little consistency or conceptual clarity about what the most appropriate approaches to addressing the environmental impacts of biobanks should be, nor indeed, what the exact environmental impacts of biobanking are.

Improving existing and future biobanking practices

Despite health researchers’ ethical positionings about the environmental impacts of biobanking, several health researcher interviewees explained that they were happy to incorporate more efficient systems within their research processes if their work remained unaffected (“if you can do things more efficiently, of course. I mean, that almost goes without saying” (health researcher interviewee 4)). Fewer health research interviewees (n = 1), though a number of sustainable digitalisation sector stakeholders, viewed the environmental impact of biobanking as such a large cost – “it’s a major cost” (health researcher interviewee 11) – that they felt a more proactive approach was required, and that future biobanks need to consider and apply the lessons learnt from other sectors to reduce environmental costs:

The compute cost of what we do is substantial, and we do have to see people and use resources. We have liquid nitrogen tanks lying around that cost money and take resource … [. .]. I think we probably should be learning from the commercial sector about how to do things at scale in a very efficient way, and I think actually studies like Our Future Health [a UK biobank that is currently being planned], which is on the horizon, will have to do that, because they will be again an order of magnitude larger than Biobank. So, there is an opportunity there.

Interviewees had varying views about how the environmental impacts associated with biobank data storage and use could be mitigated (biobank sample storage was less relevant to health researchers whose own practices relied mainly on data; sample storage was also outside the scope of digital sustainability experts). One
of the health researcher interviewees called for a regular evaluation of health benefits to ensure these still outweighed the environmental cost of the research (health researcher interviewee 7). Sustainable digitalisation interviewee 16, who was a computer scientist, called for a constant re-assessment of digital infrastructures and networks that support that data to ensure efficiency. They explained how holding health data in a data center may have been the most efficient method of storing data previously, but due to the large quantities of health data now being produced, other more localised data storage options may now be more appropriate. This interviewee explained the need to alter environmental sustainability decision-making based on circumstances. For example, this interviewee described, when a local facility collects small amounts of health data it is sustainable to store it in the cloud. When vast amounts of health data are being collected locally, it becomes more sustainable to store and analyse the data locally (“if you are pushing data to the cloud all the way, so it has to go all the way from your location to the remote”). Other interviewees – often with different expertise - mentioned other practices that could be enacted to decrease the environmental impacts of biobanking and the health research it supports. For example, sustainable digitalisation interviewee 9 discussed how moving desktop computer data to a data center could reduce energy consumption:

if I’m a researcher and I’ve got a [hard drive that] sits under my desk and … runs only when I’m in doing something on it, and I move that to cloud I’ll get a significant improvement in efficiency right? … [Moreover] … I can put a server in a cloud data centre and when it’s at idle it’ll run at 70% of its max power, or I can set it up so it’s running at 20[%]. … At 20% of power, when it’s at idle I take some risk in my response … So … you’ve got to figure out what are those trade-offs. I would argue for most researchers having a lower idle makes no difference.

In contrast, health researcher 2 took the view that reducing the size of hardware was a key aspect of reducing energy consumption:

… producing systems that require less cooling, that are more environmentally friendly, that would be the solution I guess. The smaller the hardware, hardware that doesn’t heat up that much, materials that transmit information faster without the need of that much energy, etc., etc.

Finally, sustainable digitalisation interviewee 20 discussed the need to choose a data center whose response rates and power consumption were as sustainable as possible:

they must make sure that the infrastructure that they source to store these exabytes of data are in itself sustainable so that, for example … in Norway where you have unlimited amount, amount of renewable energy … also this genomics data will have to be there for the next 20 years … then you’ve got to make a good choice right now … because what they also know, should know, the IT people, they can’t move it later on.
Finally, one interviewee suggested storing data on DVDs rather than in data centers:

I did a session … for IT in [medical] practices … I quickly found out that their website and their email is nothing. What they’re really spending a lot of money and energy on is storing all of the scans and the MRI stuff … and the, and the 3D videos … I put up a case that if they … really want to be sustainable, then they should install their own storage on site …. store it on DVD, not online … online storage also takes energy (sustainable digitalisation interviewee 2).

Despite these suggestions, interviewees – particularly those from the sustainable digitalisation sector - pointed to difficulties with quantifying the environmental impacts of the biobanking sector. This uncertainty, compounded by structural issues that imparted a lack of control over choice, and limited opportunity to make change, meant that it was perceived to be difficult for digital end users to enact environmentally responsible decision-making: “because there’s no way to quantify this is [a] more environmental technology and less environmental technology … they have no responsibility … to choose, because there is no, nothing to choose from” (sustainable digitalisation interviewee 20). In fact, many sustainable digitalisation interviewees remained concerned that uncertainty around the health research/biobanking associated environmental impacts meant that there were remaining questions around the effectiveness of any environmentally focused sector changes. In the below, sustainable digitalisation interviewee 8 explained that little evidence exists that changes in digital user practices, such as biobanking and health researcher practices that used data storage and processing, would lead to changes in environmental impact because they would have such a small impact compared to if the digital sector themselves re-designed their systems to be more efficient. This interviewee emphasised:

you need to lobby to get, like, you know, half a billion people to change their behaviour, and that’s doomed to failure and they should be focusing their attention on the things that make a big difference … so if you design your system, even a small difference in the amount of energy used by one person, if it’s used by two billion people it’s going to make a big difference.

Discussion

Most of the biobanks and health researchers that we spoke to either had no specific policies on environmental sustainability or had thought little about the adverse environmental impacts of biobanking and the research it supports. This lack of awareness is despite increasing concerns about the environmental impacts of health research and care more generally (for example, see (Eckelman, Sherman, and MacNeill 2018; McPherson, Sharip, and Grimmond 2019; Namburar et al. 2018; Rae et al. 2022)). Within the broader health sector, sustainability efforts have focused on addressing a range of environmental impacts, including the
consideration of building and facility energy costs, carbon emissions associated with travel, carbon emissions associated with various health procedures and devices (e.g. imaging, asthma inhalers) and managing waste (Samuel and Lucassen forthcoming). Attention has also focused on the environmental impacts of electronic devices used within health research and care facilities, including, for example those impacts associated with freezers, lights and computers (Samuel and Lucassen forthcoming). More broadly, environmental sustainability concerns are also being considered in research agendas from the bottom-up, as a grounds-well of activities associated with sustainability efforts are trying to make shifts towards more research practices (e.g. see UK LEAF (Sustainability Exchange)). Funding bodies are also taking their own steps to become net-zero (e.g. the UK’s UKRI (UKRI)), as are health policy agencies (e.g. the UK’s Medicines and Healthcare products Regulatory Agency (MHRA) (Medicines & Healthcare products Regulatory Agency 2021) and the UK’s National Institute for Health and Care Excellence (NICE) (National Institute for Health and Care Excellence)).

At the same time, ethical frameworks associated with sustainability efforts in the health sector are limited (with notable exceptions, for example, see (Richie 2019)). Furthermore, when the concept of sustainability is discussed – both in the health and non-health sector– it is often framed with little clarity of what sustainability means and how it should be valued (Samuel, Lucivero, and Somavilla 2022). While this heterogeneity is seen by some as a way to bring diverse scholars together (Lélé 1991), for others it has led to confusion (Oermann and Weinert 2016), and a conceptual “dead-end” (Vogt and Weber 2019). Furthermore, prominent concerns have arisen about “green-washing” (Lucivero et al. 2020), with some scholars describing sustainability efforts as a catch phrase within policy-making and broader civil society - a fashion accessory, or a brilliant slogan (Sartori, Latronico, and Campos 2014). Other scholars point to the fact that the meaning of environmental sustainability often revolves around carbon-centric approaches and fails to include other aspects of environmental impacts (Samuel, Lucivero, and Somavilla 2022; Dalsgaard 2013). This leaves questions about what a legitimate concern should be when considering the environmentally sustainability of biobanking and the health research it supports. This is exacerbated by little evidence about the exact environmental impacts of the biobanking sector, not only because biobanks are just one part of a broader digital infrastructure, making it incredibly complex to assess data storage and processing, but also because assessing embodied carbon emissions of digital infrastructures and other devices such as freezers is often plagued by a range of uncertainties, assumptions and misinformation (Samuel, Lucivero, and Somavilla 2022; Varriale 2021). Given this, it is perhaps unsurprising that our interviewees ethically justified their lack of consideration for the environmental impacts of biobanking practices and the research it supports.

Nevertheless, as imagined by some of our health researchers and many of our digital sustainability interviewees, there are various steps that can be taken to
improve existing and future biobanking practices. Suggestions drawn from the broader environmental literature include considering whether storing biobank samples at a higher temperature can be achieved without loss of sample quality, and considering the use of in-house servers to store data compared to other storage solutions such as data centers. They also include appropriate recycling and repurposing policies and practices (Cheek 2019) and developing environmentally sustainable algorithms that do not compromise on quality (Grealey et al. 2021) (and biobanks could require researchers to be open and transparent about this).

At the same time, to consider whether these changes need to be (or not) part of a standardised ethical framework, we must first understand the implicit reasoning (“unstated or taken-for-granted assumptions about what is good or bad, right or wrong, required or not required” (Carter 2018)) attached to the justification (or not) of any such framework, and these need to be settled through explicit ethical deliberation (Johnson et al. 2022; Cribb 2020). Our interviews identified a number of such implicit assumptions. For example, interviewees who appealed to what they perceived as worse problems relied on an assumption that the environmental costs of biobanking were less problematic – and in fact, a minimal concern – compared to the environmental costs from other sectors, even though this line of reasoning is a well-established ethical fallacy (Sahai, Yashmohini, and Horincar 2021). Interviewees’ reasoning which drew on consequentialist positions also contained implicit assumptions. For example, when interviewees talked about biobanks being more beneficial for the environment than pre-biobank practices, they assumed that increased efficiency would lead to lesser consumption in the long run, which has been shown not to be the case (Alcott 2005). And when interviewees deferred environmental costs to the digital sector they assumed solutions could be technological in nature, though “technological fixes” cast social situations “as neatly defined problems with definite, computable solutions” (Morozov 2013) to ecological issues (Levidow and Raman 2020; Kovacic, Strand, and Völker 2021). For example, technological solutions to the environmental impacts of digital technologies often revolve around increasing the efficiency of a digital system. However, increasing efficiency may lead to more, not less consumption (Samuel, Lucivero, and Somavilla 2022). They also shift discourses away from collective responsibility – a key element of much literature on environmental sustainability more generally (for example see Robertson 2021)). Finally, when health researchers assumed that collecting and analysing more data will lead to better health there was a lack of clarity about whose health was being considered. Many biobanks often market themselves as delivering health benefit for the common good (Kahn 2014). However, there are concerns that the type of research biobanks enable may exacerbate existing health inequalities because they concentrate health benefits to those already experiencing greater access to healthcare (Madhusoodanan 2020; Geneviève et al. 2020; Gray, Lagerberg, and Dombrádi 2017). If the health benefits of
biobanking are only distributed to some (those who can afford healthcare), questions arise as to whether the health implications of biobanking for those who cannot afford, nor access health services - where biobanking may amount to only health *risks* in the form of environmental impacts - should be included in consequentialist calculations. This is not to say that biobanking and the health research it supports is problematic, rather any legitimate ethical framework that considers (or chooses not to consider) the environmental impacts of biobanking and the health research it supports will need to be explicit about how these implicit assumptions are incorporated, and explicitly clarify the parameters under which the framework does and does not apply.

**Conclusions**

Our findings highlight that those biobanks we spoke to had limited policies on environmental sustainability, and health researchers using biobank data had little awareness about these issues. Digital sustainability stakeholder and health research interviews pointed to a lack of consistent metrics to assess such environmental impacts. More evidence about biobank associated environmental impacts is needed to help develop a consistent benchmark to assess the environmental sustainability of biobanking and the research it supports. More discussion with biobanks is also needed to understand their current sample and data practices and possible “pinch points” for change. From this, we can map out an ethical framework that engages with the nuances of ethical reasoning present in our findings.

**Notes**

1. Altruism, solidarity and nationalism are among the narratives that have been associated with the promissory of biobanks worldwide (Busby and Martin 2006; Hinterberger 2012; Tupasela 2017).
2. Also see (Biobanking.com 2021).
3. Lab sustainability is a growing field, which focuses on reducing the waste and pollution produced in typical science labs. See (“Environmental Sustainability in Biobanking”; UCL 2019).
4. Shifting to renewable energy is a partial solution, but not a technological fix (Bihouix 2020).
5. UK Biobank is the UK’s largest publicly funded health-based biobank - and one of the largest publicly funded health biobanks in the world.
6. The list of biobanks was sourced from previously published work (Gille, Vayena, and Blasimme 2020), and included mainly “resource-intensive” biobanks.
7. This list of 20 biobanks is described elsewhere (forthcoming).
8. While this analysis focused on seven interviews, and the themes generated had a different focus to the broader analysis of 24 interviews, the ideas presented fit broadly into the context of the findings from the 24 interviews.
9. Including, for example, the UK care.data scandal, and the more recent UK General Practice Data for Planning and Research (GPDPR) scandal, in which the public raised concerns about the sharing of their General Practice (GP) records with the NHS for research purposes.
10. See (“Environmental Sustainability in Biobanking”) for a discussion of these issues. Also see (n/a).
11. Data security is a (perceived) concern in this scenario, but other options are also possible for in-house storage. For example, re-purposed/more efficient hardware/software/open compute etc. Also see (Petrone 2016).

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