sustainability

MDPI

Article

The Environmental Sustainability of Digital Technologies: Stakeholder Practices and Perspectives

Gabrielle Samuel [1,*], Federica Lucivero [2] and Lucas Somavilla [3]

[1] Department of Global Health and Social Medicine, King's College London, Bush House, Strand, London WC2B 4BG, UK
[2] Ethox Centre and Wellcome Centre for Ethics and Humanities, University of Oxford, Oxford OX3 7LF, UK; federica.lucivero@ethox.ox.ac.uk
[3] Responsible Technology Institute, Department of Computer Science, University of Oxford, Oxford OX1 3LN, UK; lucas.somavilla@cs.ox.ac.uk
* Correspondence: gabbysamuel@gmail.com

Abstract: Artificial Intelligence and associated digital technologies (DTs) have environmental impacts. These include heavy carbon dioxide emissions linked to the energy consumption required to generate and process large amounts of data; extracting minerals for, and manufacturing of, technological components; and e-waste. These environmental impacts are receiving increasing policy and media attention through discourses of environmental sustainability. At the same time, 'sustainability' is a complex and nebulous term with a multiplicity of meanings and practices. This paper explores how experts working with DTs understand and utilise the concept of environmental sustainability in their practices. Our research question was how do stakeholders researching, governing or working on the environmental impacts of DTs, utilise environmental sustainability concepts? We applied a combination of bibliometric analysis and 24 interviews with key stakeholders from the digital technology sector. Findings show that, although stakeholders have broad conceptual understandings of the term sustainability and its relation to the environmental impacts of DTs, in practice, environmental sustainability tends to be associated with technology based and carboncentric approaches. While narrowing conceptual understandings of environmental sustainability was viewed to have a practical purpose, it hid broader sustainability concerns. We urge those in the field not to lose sight of the wider 'ethos of sustainability'.

Keywords: sustainability; artificial intelligence; digital technologies; qualitative research; environmental impact; sustainable development; carboncentric; technocentric

Citation: Samuel, G.; Lucivero, F.; Somavilla, L. The Environmental Sustainability of Digital Technologies: Stakeholder Practices and Perspectives. *Sustainability* **2022**, *14*, 3791. https://doi.org/10.3390/su14073791

Academic Editors: Aimee van Wynsberghe, Larissa Bolte, Jamila Nachid and Tijs Vandemeulebroucke

Received: 28 February 2022
Accepted: 18 March 2022
Published: 23 March 2022

1. Introduction

Digital technologies (DTs) allow for the datafication of things; they gather, store and process data for various uses, including machine learning technologies and other artificial intelligence (AI) algorithms. DTs are often viewed as a driver for reducing the environmental sustainability of various sectors by providing, for example, information to reduce energy consumption (DTs for environmental sustainability) [1–3]. However, DTs have their own environmental impact. This includes heavy carbon dioxide emissions linked to the energy required to generate and process large amounts of data; the impact on the material environment (e.g., where data centres are constructed); impacts linked to unsustainable practices for extracting minerals for technological components, as well as the manufacturing of these components; and e-waste disposal [4,5]. While likely improvements in energy efficiency and the move to renewable energy will no doubt relieve at least some of these concerns [6], the pace of data driven innovation raises concerns that digital technologies could outpace the world's renewable energy sources, leading to increases in carbon emissions when other sectors are decreasing their energy use [7,8]. Furthermore, data driven solutions have rebound effects, meaning that, while digital solutions in the near term may appear to offer environmental advantages in terms of increased efficiency, in the long run, this will lead to increases in demand for digital technologies, data storage and analyses, not a reduction [9–11].

While, over the past decade, concerns about the environmental impacts associated with DTs have been increasingly discussed in the digital sector [12,13], more recently, they have received policy and media attention [14–16]. A range of sector associated initiatives and practices are emerging bottom up [17], building awareness about sustainability issues, and helping accelerate understanding in the sector. Many hyperscalers have pledged net-zero commitments, as well as other environmental commitments, often revolving around notions of sustainability [18,19]. Similar to many other sectors, sustainability reporting associated with the environmental impacts of DTs is now becoming a feature of many companies and organisations [20]. As it has been noted that the environmental impacts of DTs should be a topic for discussion in the ethics and politics of digital data and AI literature [21], sustainability is also being increasingly called for by scholars in this field. For example, the European High Level Expert Group on AI states that responsible AI should be sustainable and environmentally friendly [22], Van Wynsberghe argues that sustainable AI is the third wave of AI ethics [23], and Tamburrini (2022) explores the responsibilities of AI scientists for the carbon footprint of their work [24].

At the same time, whilst sustainability is most notably defined as being associated with 'sustainable development' that considers not only financial profits but also social and environmental factors [25], the term 'sustainability' has a long history of being a complex and nebulous concept—it has different pillars and dimensions, and a multiplicity of meanings, which are neither stable nor fixed [26]. This is because the meaning of policy relevant terms such as 'sustainability' is not 'hardwired into social reality', but requires interpretation [27], and will be 'read' differently by various audiences [28,29]. Meaning is not universal or determinate, but depends on the context and the perception and interpretation of those who are enacting it [28]. Different scholars place different weight over whether sustainability is more about economics, ecology, or social science, as well as whether it should address technology, resources, waste, pollution and/or other issues [30–32]. Furthermore, meanings may be inferred from a philosophical, technical, or ethical perspective [30]. Many sustainability initiatives are also perceived to be an attempt at 'green-washing', and concerns have been raised about sustainability initiatives being reliant on the objectification of carbon driven by neoliberal markets [33,34]. While, for some, this heterogeneity of the sustainability concept allows it to act as an umbrella concept [35], the ambiguity, confusion and lack of clarity around how to apply the concept is highly problematic [36–39].

We explored how experts working with DTs and sustainability understand and utilise the term in their practice. In particular, our aim was to explore how those considering, researching, governing and/or working on the environmental impacts and/or sustainability of DTs, are drawing on the concept of environmental sustainability in their own work. Our research question was how do stakeholders (academics, researchers, NGOs, policymakers etc) researching, governing or working on the environmental impacts of DTs, utilise environmental sustainability concepts? We applied a combination of bibliometric analysis and 24 interviews with key stakeholders from the digital technology sector.

Findings show stakeholders have broad conceptual understandings of the term sustainability and its relation to the environmental impacts of DTs. However, in practice, environmental sustainability tended to be associated with technology based and carbon-centric approaches. These approaches have been criticised in other fields because they hide broader sustainability concerns. This was evident in our findings too. While narrowing conceptual understandings of environmental sustainability was perceived to have a practical purpose, technology based and carboncentric approaches alone cannot address sustainability. Those in the field must not lose sight of the wider ethos of sustainability, though, at the same time, to do so requires changes in the socioeconomic and political climate.

2. Materials and Methods

2.1. Interviews

The inclusion criterion for interviews was having expertise in the field of digital environmental sustainability [17]. Sampling was purposive. Participants were identified via two approaches. First, bibliometric analysis identified key academics researching in the field of digital environmental sustainability (see below). Second, snowballing that included (a) asking key stakeholders in the field known to the authors to provide a list of relevant individuals working in the sector, and (b) asking interviewees if they knew other individuals who would be useful to talk to. Seventy-three individuals were contacted via email and asked to participate in an interview. Twenty-four individuals accepted the invitation and interviews were conducted online or on the phone. Interviews were conducted primarily with individuals based in the UK and continental Europe, though also in continental North America (n = 3) and Australia (n = 1). Interviewees self-reported as being associated with a range of sectors (Table 1; note, some individuals self-reported as crossing more than one sector). Interviewees were primarily male (n = 17; see limitations). No other demographic criteria were collected because, as is often the case with expert interviews, we were more interested in exploring the different ways that stakeholders were drawing on the concept of environmental sustainability in their own work, rather than correlating this to particular demographic criteria.

Table 1. Self-reported sectors of interviewees. Some individuals self-reported as being associated with more than sector, and in the table they have been marked as both, which explains the higher total compared to the number of interviewees.

Sector	**Number of Individuals Self-Reporting as Belonging to a Sector**
Academic researchers (computer scientists, sustainability experts, social scientists, engineers, societies)	10
Industry (commercial, corporate, spin offs; directors, researchers, alliances/organisations)	8
Data centre representatives or consultants, or involved with the sector's markets	5
Policymaker/consultant (funding bodies, organisations associated with standards	5
NGO	1

Interviews were designed to be exploratory, and the interview schedule was broad. Interviewees were asked about their roles and work practices (job role and/or research area; how their role was relevant to DTs (e.g., their research, their interests, their industry etc)), their understanding of the term sustainability; how environmental sustainability was being incorporated into their own practices and their perceptions about how it was being drawn upon in the digital sector more generally; and the actual and perceived challenges associated with this. Interviews were semi- to unstructured. This meant that, by the end of the interview, the interview schedule was covered, but the interviewer would also let the interviewee lead the interview in other directions if they chose, and asked impromptu questions associated with new issues if they were raised. Interviews lasted 32–92 min, with most interviews being between 50–70 min.

Interviews were transcribed by an external transcriber, and these transcripts were analysed via inductive thematic analysis. Thematic analysis is one of the most well established approaches for analysing qualitative data (for example, see [40]). Our inductive analysis approach aligned with the approach taken by Braun and Clarke [41]. GS and a research assistant independently read and re-read each interview transcript to familiarize themselves with the data. Both coders made extensive memos as they proceeded through this step.

GS and the research assistant then independently coded the data. In depth meetings were held on a number of occasions to discuss relevant codes and overlaps. For this paper, codes associated with the meaning ascribed to the term sustainability were considered relevant for analysis. GS combined the codes and drew on them to develop themes.

2.2. Bibliometric Analysis

On 12 February 2021, articles in Web of Science published between 2016–2021 were searched using four separate keyword string combinations (Supplementary Materials: Table S1). Keyword strings were developed deductively and inductively through an iterative process, and combined a range of keywords relating to the environment, sustainability and the need for energy efficiency, alongside a range of keywords related to digital technologies. Specific keywords particularly 'noisy' during the inductive searches were removed from this main keyword string, and created as separate strings. In total, the combination of all the keyword strings returned 4598 articles.

Titles and abstracts of articles were reviewed for the inclusion criterion—articles that explored or discussed the environmental impacts of DTs. Initially, the inclusion criterion was independently applied to 100 articles by a research assistant, GS and FL to ensure consistency of approach. Discrepancies emerged and were discussed, with a refinement of review that included exclusion criteria. The process was repeated twice more until consistent. An exclusion criterion included articles that discussed environmental impacts, but those environmental impacts were not specifically associated to the digital aspects of the technology. The research assistant then applied the inclusion/exclusion criterion to the remaining articles. Following this, 489 articles remained.

A coding schedule and manual was deductively developed to analyse the articles. The coding schedule was applied to 30 articles by a research assistant and GS. Discrepancies were discussed and the coding schedule was inductively refined to ensure consistency. Codes included: main academic field of the research based on the keywords of Web of Science; explicit reference to climate or sustainability risk or problem as a motivation or justification for research; type of DT that was the subject of analysis; sustainability or other issue addressed; approach used to address the issue (Supplementary Materials: Table S2). GS and the research assistant duplicate coded a further 10 articles and achieved 96% similarity between all codes coded. GS and the research assistant discussed the discrepancies and slight changes were made to the coding schedule/manual. The remainder of the articles (449 articles) were coded by the research assistant with the updated coding schedule/manual.

2.3. Limitations

First, Web of Science contains bibliographic information from a set of more than 7500, primarily English language journals. Fields that publish heavily in the journal literature, such as the sciences, are better covered than those that do not, such as philosophy. Therefore, some subject areas are poorly covered, including business and education. Nonetheless, Web of Science is one of the broadest academic databases, covering a wide range of subjects. Second, our sample of 24 stakeholders did not capture the whole digital sustainability landscape. However, this was not our intention. Rather, we aimed to speak to key stakeholders who could give us a better understanding of the issue. Though we do note that none of our interviewees were residing in low to middle income countries, and further research should explore the views of such stakeholders. Furthermore, we did not have an equal gender balance of interviewees. When identifying potential participants for interview, they were mainly males, most likely reflecting the gender bias of the workforce (see, for example, [42]). Further research should aim for a higher female representation.

3. Results

3.1. Sustainability as a North Star

Interviewees considered sustainability as a universally accepted value that guides people's actions. At the same time, interviewees viewed sustainability as an ill-defined abstract concept that is hard to measure and action.

When interviewees were asked about how they would define the term sustainability, or how sustainability was defined within their sector, they framed the concept using the well-established notion of encompassing economic, environmental and social factors into the development processes: *'you have to look at it [development] systemically, for a start, you can't look for things in isolation. It must include the environmental, it must include the social, and it must include the economic'* (interviewee 13). At the same time, interviewees echoed discussions in the literature that have questioned the term's usefulness as a metric to align themselves with when considering their own development or business practices: *'I think that sustainability is . . . it's almost too broad to be useful as a term'* (interviewee 12). Participants pointed to the well established confusion about what the term 'actually means' in practice: *'I think there's still a debate on what do you actually mean with all this . . . If I talk to the economists here . . . I have a different view, and they have a different view . . . '* (interviewee 1). Interviewee 19 reflected on the different understandings of sustainability promoted by 'zealots' and 'pragmatists': *'there's a definition created by the group that I refer to as the zealots . . . people that use sustainability . . . as a religion . . . Then there's the pragmatists . . . So . . . it's . . . how you really manage this'* (interviewee 19).

This left questions about how individuals and businesses should approach the notion of sustainability, understand what this concept means and/or decide how they need to change their practices to achieve it. Furthermore, interviewees were concerned that, because the concept of sustainability is opaque, it can be used by industry as a greenwashing strategy. One of the respondents, participant 6, explained how encapsulating everything under sustainability becomes problematic because, with so many definitions of sustainability circulating, it can lead to confusion in terms of standards and practices, which businesses can play to:

> *'no one really properly defines what sustainability actually means when it comes to reporting. And then when there is reporting, it's not standardised. It's not consistent. And it is often just hidden in environmental reports that look really nice and have a lot of good photos but are very difficult to compare. So as a, as a researcher, or a consumer, or a business trying to make a decision on what is, what is the more sustainable product, if you're trying to make a comparison between different options, it's basically impossible to do'.*

Despite this, many interviewees had a general sense that sustainability, and the more specific sustainable development goals (SDGs) [17], were a 'target to reach' (interviewee 14). They were a universal value—something shared by different people—a 'North Star' (interviewee 22) that brought consensus to the field in terms of aspiring towards an ideological ethos of sustainability. This can be considered as a Kantian regulative ideal [43,44]—a goal to be approached, that we may never reach but that guides our actions:

> *'sustainability . . . [is] about people, economy and the planet . . . the common language that all of us speak are the sustainable development goals and that's really been the main basis of our work . . . it doesn't matter what sector, what region of the world. We have these, we have this North Star . . . '* (interviewee 22);

> *'there is more consensus now, also in the line of the SDGs that are another big international agreement and target to reach . . . and no one should be left behind. Besides the economy . . . there is the big issue of environment and social justice'* (interviewee 14)

However, beyond this abstract conceptualisation of sustainability as a guiding principle, in decision making and agenda setting in the DT sector, the principle of sustainability—and more specifically, environmental sustainability—was actioned in a variety of ways that often were narrowed down to a single or two dimensions.

3.2. Practices of Narrowing down Environmental Sustainability to a Single or Two Dimensions

Participants stressed that a combined approach to addressing environmental sustainability was needed—one that focused on carbon reduction, but also on decreasing the use of resources through increased efficiency, addressing water consumption, and promoting biodiversity. In the below extract, one participant (interviewee 4) discusses the need to optimise both water and energy efficiency to ensure stability in the operations of a data centre, as well as consider carbon emissions and the circular economy—*'it's not just a single dimension'* that needs focussing on, explained interviewee 14, *'but multiple dimensions'*. Participant 4 remarked:

> *'people are starting to talk about water usage effectiveness, carbon usage effectiveness. People are starting to measure efficiency in terms of how much performance you get from the energy that you use rather than it having anything to do with cooling ... Circular economy is becoming an increasing area of focus ... things like load balancing as well is another area of interest ... '*

Participant 21 also described the development of a data centre through sustainable practices that included considerations of carbon emissions, efficiency and low waste:

> *'this is a great story of ... An end-to-end sustainability offering ... This company takes a containerized data centre that might fit between say ten or 8 to 12 racks of hardware. They sit next to a greenhouse ... They use the heat from that container ... so they sell the heat to the farmers while they're producing a distributary grid ... and all of that hardware is second user decommissioned ... that has very low Scope 3 emissions because it's already been in the ecosystem, reusing the heat for agricultural purposes and running highly efficient hardware'.*

Although most interviewees were aware that the concept of environmental sustainability had these multiple dimensions, there was a perception that this combined approach was not mainstream. They worried that the concept was often narrowed down to only one or two actions pertaining to environmental sustainability—most notably associated with either the efficiency dimension or carbon emission. For example, interviewee 8 explained that focussing on carbon dioxide/greenhouse gas (GHG) emissions was a key concern: *'if a company says it [talks about sustainability] then it usually means, how can we reduce our greenhouse gas emissions? ... That's what they would be focussing mainly on'*.

3.3. Increasing Efficiency and/or Decreasing Carbon Emissions as a 'No Brainer' in a Business Sense

Interviewees explained that, with so many business pressures to remain profitable, it made sense for businesses to begin addressing environmental sustainability in the area that would have limited effect on finances, and the relationship between increasing efficiency and the financial goals of a business made these appealing places to start. Increasing the efficiency of DTs has been a historic 'business driver' for the ICT industry because of its inextricable link to saving money, long before the environmental sustainability movement. Interviewees explained that it was a 'no brainer' (interviewee 10) for companies to focus on efficiency gains to become (in their perceptions) more environmentally sustainable:

> *'when it comes to, you know, environmental impact or sustainability in data centres ... business drivers behind these are ... in terms of energy efficiency ... Rather than spending 100 megawatts of energy on ... my energy consumption ... I can only spend 50, well actually that puts me in much better position ... when you do the numbers'* (interviewee 11);

> *'green IT, sustainable IT, was originally about making data centres more efficient ... [it was also about companies wanting] to say, "we want to sell you green data centres ... and it's gonna save you money so buy it from us." That's ... the kind of, sell point'* (interviewee 8)

Addressing carbon dioxide/GHG emissions was also perceived by interviewees to make appealing business sense, especially when it was—and it often was—tied to increased efficiency (increased efficiency meant less energy used, which meant fewer carbon emissions): *'there is a direct relationship between financial costs and carbon emissions. The lower the financial cost of your solution ... the lower your carbon footprint will be'* (interviewee 13); *'there's ... good business reasons that they're doing this ... they're not doing it just purely out of, "Oh you know, we want to be environmentally friendly"'* (interviewee 10). Interviewees also narrated a range of other reasons they perceived individuals and companies to be pursuing environmental sustainability through a focus on carbon/GHG emissions. They were aware of the various benchmarks that focused environmental sustainability efforts on carbon emissions, and these were seen to provide a goal for businesses and organisations to 'aim towards': *'it's not easy but it's easier if you sort of give people a kind of benchmark and say, "Right, you really should aim towards that"'* (interviewee 7). Regulations in the sector were perceived to be forcing industries to assess, monitor and minimise their carbon/greenhouse gas emissions: *'[the focus on carbon has] a lot to do with government regulation forcing those standards'* (interviewee 6). Some interviewees considered how this needed to be considered in a geopolitical context, because some countries were more set up to address these issues than others, and had more accommodating regulatory environments: *'it's a little bit easier [in Europe to consider these issues]'* (interviewee 22). Finally, strong pressure to consider these issues was considered to have come from peers (*'everyone's worrying about emissions because they have to, because of law, but also because everyone else is'* (interviewee 12)), as well as from consumers:

> *'there's been growing consumer interest in this as well ... companies ... probably want to develop or maintain an image that they are, you know, not polluting or green and that the services people are using are powered by clean electricity'* (interviewee 10)

These factors often led to a carboncentric approach to environmental sustainability, despite an understanding of its limitations. For example, interviewee 23 explained how the global sense of urgency to reach net-zero carbon emissions meant that their work was focusing primarily on reducing carbon dioxide emissions: *'the expectation is that the EU [European Union] require that 2050 the whole of Europe is carbon neutral so we are looking mainly at the carbon emissions, the $C0_2$ emissions of electricity'*. In the extracts below, two interviewees provided further examples of where a choice was made to focus on a carboncentric construction of sustainability, despite an understanding that sustainability is a much broader issue. First, interviewee 3 explained that their reasoning for refining the scope of a large report around issues of carbon, rather than the environment as a whole, was based on the fact that there was more media attention on this issue. Second, interviewee 18, who worked with the sustainability department of an organisation, explained how, while they were looking at more than carbon issues when focusing on environmental and social sustainability, it was easier to talk about carbon to their clients because they were more familiar with the issue. In both instances, while they themselves had a broader understanding of sustainability, they were perpetuating a construction of sustainability that was carboncentric:

> *'if we took all the environmental impact, we would probably have published a 10,000-page document. So, we had to refine ... and emissions seemed to be a really interesting area because there was quite a, a lot of controversy in the media, a lot of uncertainties ... Something that's come up in some of our follow-on meetings is that ... environmental sustainability is ... more multidimensional ... thinking about biodiversity'* (interviewee 3);

> *'I'm just looking from the carbon, because when I talk to customers it was the easiest question, because now it's like everyone wants to have a carbon index on what they are buying ... but internally we are tracking many other indicators [of sustainability]'* (interviewee 18)

3.4. A Carboncentric and Technocentric Approach: A Very Narrow Frame That Misses the Bigger Picture

Some interviewees were concerned that a focus on benchmarks, regulations and profit was leading to the concept of environmental sustainability being viewed solely in terms of metrics, and that, together, carbon emissions and/or efficiency gains were being conflated with environmental sustainability as a normative concept. Interviewee 18 described how, in terms of efficiency *'many people think it's [sustainability is] … not taking all the pillars of sustainability, just more focussed on efficiency than really … caring for environments or caring for the planet'* (interviewee 18). This worried interviewees, who viewed sustainability as a broader concept: *'we can help them [our clients] with the energy efficiency … If they want to put it within … the sustainability banner, fine, we'll support it, but, but I'll be really reluctant to call that sustainability*' (interviewee 11). Interviewees were concerned that approaching sustainability in this narrow sense detracted attention from other elements associated with sustainability—not just water and waste, but also more hidden issues, such as those related to toxins that may be produced during electronic manufacturing processes [45]: Interviewee 7 remarked on the carboncentric drivers pushing companies to account for their carbon emissions:

> *'this is the, the danger of drivers in a way, isn't it? … They can almost forget about the other stuff, you know, and just because you're being presented with ways of achieving these targets and you're going to get a pat on the head for doing it, and, and it's harder to think about the other stuff … [for example] … you might have something that's very low carbon, but actually it's incredibly toxic to water or, you know, human beings … you need to look at the biggest picture possible … Some people … think about energy … and that's it'.*

Participant 17 concurred: *'certainly carbon accounting is important, but … once you focus only on that … you create a very narrow frame … carbon is not toxicity … there are always problems [with what] … you choose to count and what gets left'.*

However, there was also a realisation that, while addressing environmental sustainability was viewed as something relatively achievable for larger companies, trying to be environmentally sustainable posed difficulties for smaller companies. Participant 21 provided an example:

> *'[a partner] ran the numbers for a company that was looking at moving [to be more sustainable], they say "Look, I can save [you] 4% on [your] energy bill" … And they say "It's just not worth it … it needs to be 25 to 30% gains" … And that's a lot. And then, even if [it is that much] Dell and HP come along and say "Well I'll just cut my price, 15%" … And the guy goes "Oh great, I don't have to learn anything new, I'll just stick with [them]" … Everyone has a different measurement on their sustainability'.*

As interviewee 19 explained, to be properly environmentally sustainable required having a good sustainability plan, and this, described this interviewee, *'takes a lot of resource'*. Other interviewees concurred: *'to move towards a sustainable infrastructure, it's gonna be huge and it's gonna be costly and time consuming'* (interviewee 21); *'it's costly, it's expensive, nationwide there may not be mechanisms in place, so there's just no motivation for some companies to do that'* (interviewee 22). Interviewee 1 reflected on this cost when describing the environmental impacts of mining, remarking on how these impacts are not often addressed because of the resource required:

> *'one of the most damaging things we see in, in the supply is, is actually the left waste of metal mining … we need to control those waste parts, or waste for thousands of years … the thing we should do is put back as it was, but we, that will cost too much … '* (interviewee 1)

3.5. Broader Conceptualisations of Sustainability: The Economic and Social

While not the focus of our interviews, a number of our participants—experts in sustainability—discussed environmental sustainability in relation to the pillars of economic growth and social justice (*'we like to emphasise there are other environmental impacts than just $C0_2$ emissions . . . there is also a hoard of social issues'* (interviewee 23)), because economic, environmental and global justice issues were perceived to be connected: *'they're very hard to decouple'* (interviewee 5). Participant 15, whose business was repurposing hardware as part of a circular economy, reflected on how they were trying to bring social sustainability considerations into their business to address this missing social component:

> *'we try to . . . think about how we can bring this recertified equipment into the parts of the world that are most disadvantaged . . . people whose children . . . are deep in mines mining cobalt that goes into electronic devices, under the most hazardous working conditions, . . . [or] . . . [whose] . . . children, they are making, you know, 20 cents a day picking through [piles of e-waste] to find a piece of gold'.*

Concerns were raised that a focus on environmental sustainability was deprioritising geopolitical social justice issues. Interviewee 23 explained how environmental sustainability benchmarks and metrics in Europe have led to the obscuring of sustainability issues associated with global environmental inequalities:

> *'in Europe it looks like our economy is reaching decoupling . . . Decoupling meaning that you get more profit whilst your environmental impact is lower. So, we are kind of fooling ourselves to saying that Europe is doing good . . . it only means that the environmental impacts happen elsewhere . . . where the materials have been mined or processed . . . our current metrics are not sufficient to show this inequality'* (interviewee 23)

Interviewee 1 described how they 'bumped into' social justice issues when considering environmental sustainability, but that, while sustainability measures exist for the latter, their experience led them to believe that less work had concentrated on the social justice component:

> *'social, I think that is something that, that we sort of bumped into very early on when we started [looking at environmental sustainability] . . . Where are you sourcing your metals? . . . Tantalum used to be the first one we talked about, coming from Africa, it's a large source . . . now cobalt is the main metal . . . [you cannot address this in terms of] life cycle assessment, so you have to treat that in some other way [as there is no other way to assess it] . . . especially when you're talking about the, the impact on . . . human health'* (interviewee 1)

Finally, one interviewee highlighted the tension between environmental and social justice, which were not always aligned, and their concern that the drive to be environmentally sustainable could lead to social injustices. Interviewee 17 described:

> *'those [environmental and social issues] are incommensurable, right. I want carbon mitigation, I do, but I also do not want to continue to colonise . . . the land of indigenous people [where this is occurring]. That's a major contradiction right, between carbon accounting and mitigation, and all that kind of stuff and social justice'.*

3.6. Bibliometric Analysis

Our bibliometric analysis echoed our interview findings. Nearly all 489 analysed articles framed their approaches within the broader discourse of sustainability (90%). Over four-fifths of the articles adopted a technocentric approach to addressing the environmental impacts of DTs (85%), i.e., they analysed or explained an environmental impact that was of concern and outlined a potential technology based solution ('solve and explain': Figure 1). This can be explained by the fact that most articles were classified by Web of Science as coming from a technology focused discipline: computer science (45%), engineering (19%) or science and technology (12%). Only 1% of the articles were classified by Web of Science as social science.

Within the articles adopting a technocentric based approach, about two-thirds of the authors were solely focused on trying to decrease the energy consumption of DTs through energy efficiency improvements (see Figure 1; 'energy'). Just under a quarter of the articles focused on addressing one or more environmental impacts (Figure 1; 'general'), and these were predominantly associated with improving energy efficiency and reducing carbon emissions (not shown in diagram). This meant that, together and reflecting the interview findings, nearly all technocentric articles we analysed were trying to address either the energy efficiency of DTs and/or their carbon emissions. Environmental impacts associated with e-waste and other issues, such as biodiversity and water consumption, have received little attention in the literature.

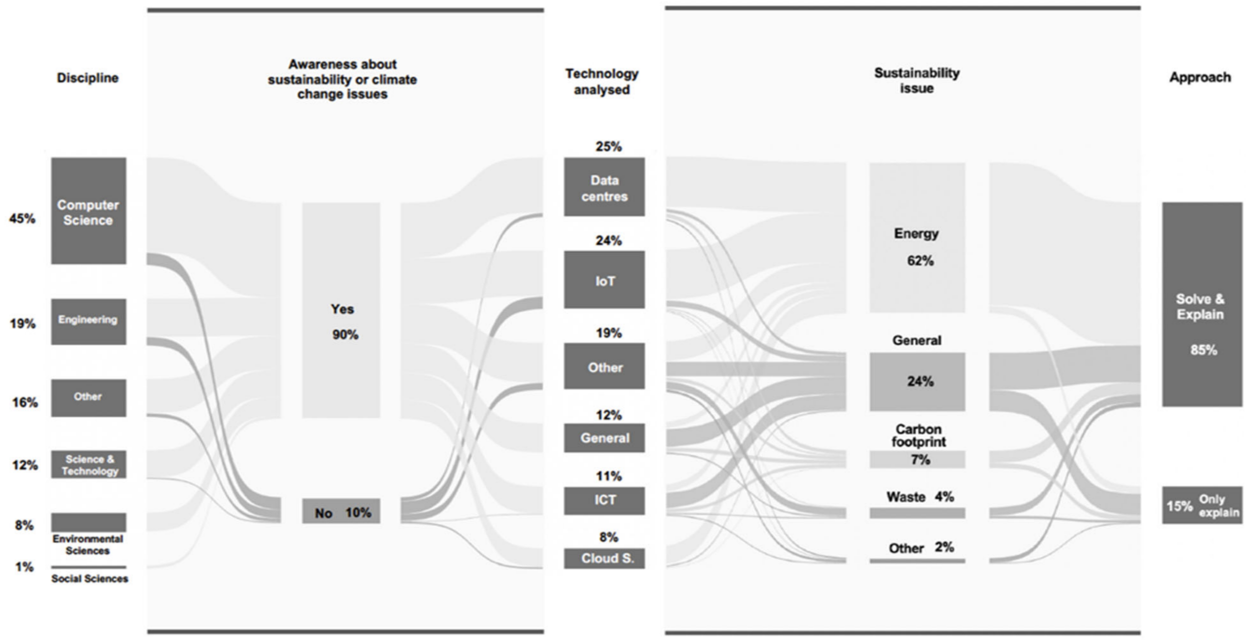

Figure 1. Sankey diagram of research articles published between 2016–2021 that explore the environmental impacts of digital technologies. Of the 489 articles retrieved from our bibliometric analysis, they were coded into five themes: main academic field of the research; explicit reference to climate or sustainability risk or problem as a motivation or justification for research; type of digital technology that was the subject of analysis; environmental/sustainability issue addressed; approach used to address the issue.

4. Discussion

Interviewees had broad understandings of the concept of sustainability and its association with the environmental impacts of DTs, however, the way the term was operated in practice varied. While, at the higher level, there was general consensus on what was meant by the term sustainability—albeit with some interviewees pointing to the vagueness of the concept; in practice, the meanings applied to the term differed. Some practices dominated more than others, with a focus on addressing carbon emissions and/or energy efficiency predominating. These interview findings were supported by our bibliometric analysis, which suggested that most published academic articles on the environmental impacts of DTs focused on improving energy efficiency and/or carbon emissions through technocentric approaches. Few articles had taken a wider approach to exploring the environmental sustainability of DTs. Together, both sets of findings suggest that, in this field/sector, sustainability is often associated with narrow, technocentric and/or carboncentric approaches.

It is understandable that a broad regulative principle such as sustainability needs to be narrowed for practical purposes in the DT sector. Moreover, it is understandable that, in academia, this narrowing will reflect those disciplines working in the field (technology driven computer science and engineering), and in the broader sector this will reflect other competing business and sociopolitical agendas. However, the shift from theory to practice has some implications. For example, it renders the concept of sustainability open to interpretation, so it can be used to justify different types of interventions (efficiency, carbon accounting, biodiversity, water consumption, etc). In the broader sector, it also permits the concept to sometimes be a catch all phrase that allows a wide variety of changes to be categorised as sustainability as a means of justifying business as usual approaches (for example, efficiency gains in line with historical business models). This produces ambiguities and tensions with significant implications for social, political, and ecological change [34]. In light of this, we note two implications associated with the narrowing down of the sustainability concept that raise concern.

First, with a 'spotlight' on carbon emissions, and a range of metrics and regulations associated with the climate agenda, it is unsurprising that this has become an academic and stakeholder focus. Using metrics is surely important, especially when it comes to carbon metrics associated with the development and deployment of AI. In fact, there are urgent needs to generate transparency frameworks that clarify how the digital sector is addressing issues of governability and standards to guide best practice in carbon accounting, social awareness of digital technologies' environmental impacts and response measures to complex dynamics emerging from the rapid development of DTs. Furthermore, once the sustainability properties of digital technologies are identified and standardised, they have to be regulated in ways that increase transparency and accountability of environmental impacts. However, using metrics too much means that sustainability is narrowed to something that is documented as 'done' [46]. This loses an important aspect of sustainability, the fact that it guides actions as a 'regulative ideal' or, as one interviewee stated, a '*North star*'. Our interviews suggest that this guiding role of the concept of sustainability, albeit recognised by our interviewees and seen in the bibliometric analysis, has not become a widespread aspect of their practices in the sector. Vitally, relying on metrics means that, when there are no metrics, issues are invisible and therefore not considered [5,33]. This was evident in one of our respondent's remarks, who explained how the focus on environmental sustainability is hiding social justice issues, and that this also correlates to having metrics to measure the former but not the latter. This narrowing down also implies neglecting important aspects pertaining to the concept of sustainability, such as issues related to other environmental impacts besides carbon emissions [47]. This was evident in our bibliometric analysis. When the meaning of sustainability is narrowed down, the bigger picture gets lost.

A second implication of the narrowing down of the concept of sustainability in specific practices is that technocentric approaches focusing on efficiency gains are limited in scope. They fail to consider issues associated with rebound effects, that is, that efficiency gains will likely lead to increases in demand for data storage and analyses, not a reduction [9–11]. This means that if the digital sector really wants to attain sustainability it is likely to be complex, difficult and costly, and also require a shift in practices. It is unlikely that technically driven solutions will be able to carefully consider what sustainability means for society at different levels. This means that companies may not always be able to conciliate between their business needs and broader sustainability goals. As our interview findings show, in particular, a conciliation between business models and sustainability goals often happens when sustainability is understood and enacted in terms of efficiency. However, to take sustainability seriously means prioritising sustainability at least equally, if not more so, than financial drivers. Unfortunately, current competition between business and sociopolitical agendas makes this difficult for individual companies. The little academic literature outside of technocentric approaches also provides little guidance on how to address these issues. To drive sustainability in the sector, changes are needed in the sociopolitical and economic climate, and, in fact, a number of our participants pointed to the need for this. This requires viewing AI, 'not as benign or neutral but as a reflection of capitalism and an instrument of power' [48], such that to address AI sustainability requires addressing key political and economic issues tied to economic growth and a lack of regulation in the drive for power and consumption [49].

In conclusion, as the concept of environmental sustainability has been translated from a 'regulative ideal' into the practices of the digital sector, it has mutated to a technocentric and carboncentric approach that fails to consider broader sustainability issues. We have problematised this in various ways. Our goal is not to criticise those working or researching in the sector, many of whom are doing their utmost to try and ensure their practices are sustainable, or are working to promote sustainable practices in the sector more broadly. Rather, we wish to expose the implications associated with adopting such a narrow sustainability focus and encourage stakeholders to differentiate between narrowed down activities and a broader sustainability ethos that they adopt in their practices. Stakeholders, including researchers, need to be able to zoom in and out between a narrowed approach (e.g., related to metrics) and a broader 'ethic of sustainability'. Seeing the concept and value of sustainability as having a dual role—both at the higher abstract level, as well as at the more local specific level—allows for splitting the usefulness of the concept into two by simultaneously using it as a way to drive an 'ethos of sustainability', as well as targeted interventions that can have a measurable and impactful change [50]. This two pronged approach allows culture change by instilling an ethos of sustainability in all layers of research, as well as in all layers of an organisation, creating a consistent message and support for this approach, while alongside, targeting specific interventions to provide an opportunity to create test beds at 'pinch points' where sustainability is vitally important [50]. To use an example from our interviewees (which is not discussed in our findings), a company delivering digital goods to people in lower and middle income countries is not sustainable if it does not also ensure appropriate payment of workers in the supply chain. In the research sector, a field in which sustainability is addressed using mainly techno–scientific approaches could benefit from more social science and ethics input. Across the digital technology research sector and industry, actors must build on coordination capabilities and a shared understanding of sustainability that includes the broad ethos of the concept, as well as its functions and limitations. At the same time, we must be careful not to shift responsibility too much onto those working in this area to develop meaningful practices to address environmental sustainability. Rather, meaning and practices associated with an ethos of sustainability need to be embedded within policy and regulatory decisions that are associated with this research and industry sector. To address sustainability issues in the digital technology sector is a collective issue.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14073791/s1, Table S1: Key-strings used for searching the academic literature on Web of Science and Table S2: Coding schedule for coding the academic literature.

Author Contributions: Funding acquisition, conceptualization, methodology: G.S. and F.L. Formal analysis, G.S. Writing—original draft preparation, review and editing: G.S., F.L. and L.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the British Academy grant number: SRG20\201487 and the EPSRC grant number: EP/V042378/1.

Institutional Review Board Statement: This study received ethics approval from the Oxford University Central University Research Ethics Committee (CUREC): reference: R75723/RE001.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Empirical data is available on request, as long as it adheres to the consent received from our interviewees.

Acknowledgments: We are extremely grateful for our interviewees' time, and also grateful to our research assistant, José Resendiz Garcia, who helped us with the bibliometric analysis.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. European Commission. 2019. Available online: https://energy.ec.europa.eu/topics/energy-system-integration/digitalisation-energy-sector_en (accessed on 27 February 2022).
2. Junge, A.L.; Straube, F. Sustainable supply chains—Digital transformation technologies' impact on the social and environmental dimension. *Procedia Manuf.* **2020**, *43*, 736–742. [CrossRef]

3. Nishant, R.; Kennedy, M.; Corbett, J. Artificial intelligence for sustainability: Challenges, opportunities, and a research agenda. *Int. J. Inf. Manag.* **2020**, *53*, 102104. [CrossRef]
4. Marks, P. Blood Minerals Are Electronics Industry's Dirty Secret. New Scientist. 2014. Available online: https://www.newscientist.com/article/mg22229734-800-blood-minerals-are-electronics-industrys-dirty-secret/ (accessed on 27 February 2022).
5. Lepawsky, J. *Reassembling Rubbish*; MIT Press: Cambridge, MA, USA, 2018.
6. Giles, M. Is AI the Next Big Climate-Change Threat? We Haven't a Clue. Available online: https://www.technologyreview.com/2019/07/29/663/ai-computing-cloud-computing-microchips/ (accessed on 28 February 2020).
7. Blair, G. *A Tale of Two Citites: Reflections on Digital Pollution*; Patterns: New York, NY, USA, 2020. Available online: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7427557/ (accessed on 27 February 2022).
8. Freitag, C.; Berners-Lee, M.; Widdicks, K.; Knowles, B.; Blair, G.S.; Friday, A. The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations. *Patterns* **2021**, *2*, 100340. [CrossRef] [PubMed]
9. Alcott, B. Jevons' paradox. *Ecol. Econ.* **2005**, *54*, 9–21. [CrossRef]
10. Hilty, L.M.; Köhler, A.; Schéele, F.V.; Zah, R.; Ruddy, T. Rebound effects of progress in information technology. *Poiesis Prax.* **2006**, *4*, 19–38. [CrossRef]
11. Takahashi, K.I.; Tatemichi, H.; Tanaka, T.; Nishi, S.; Kunioka, T. Environmental impact of information and communication technologies including rebound effects. In Proceedings of the IEEE International Symposium on Electronics and the Environment, Scottsdale, AZ, USA, 10–13 May 2004; Conference Record, pp. 13–16.
12. Ensmenger, N. The environmental history of computing. *Technol. Cult.* **2018**, *59*, S7–S33. [CrossRef]
13. Belkhir, L.; Elmeligi, A. Assessing ICT global emissions footprint: Trends to 2040 & recommendations. *J. Clean. Prod.* **2018**, *177*, 448–463. [CrossRef]
14. Schwartz, J. Tech's Environmental Impact and What You Can Do About It. *New York Times*, 2019. Available online: https://www.nytimes.com/2019/11/06/technology/personaltech/techs-environmental-impact-and-what-you-can-do-about-it.html (accessed on 27 February 2022).
15. Gilmore, M. Expert and Stakeholder Consultation Workshop 2018. Available online: https://www.eclab.uel.ac.uk/?p=5301 (accessed on 27 February 2022).
16. Department for Environment, Food & Rural Affairs. Greening Government ICT and Digital Services: 2019 to 2020 Annual Report. 2021. Available online: https://www.gov.uk/government/publications/greening-government-ict-and-digital-services-2019-to-2020-annual-report (accessed on 27 February 2022).
17. Sustainable Web Manifesto. Available online: https://www.sustainablewebmanifesto.com/ (accessed on 27 February 2022).
18. Microsoft. Available online: https://www.microsoft.com/en-us/corporate-responsibility/sustainability/report (accessed on 27 February 2022).
19. Amazon. Available online: https://sustainability.aboutamazon.com/pdfBuilderDownload?name=sustainability-all-in-june-2020 (accessed on 27 February 2022).
20. Armstrong, A. Ethics and ESG. *Australas. Account. Bus. Financ. J.* **2020**, *14*, 6–17. [CrossRef]
21. Lucivero, F. Big data, big waste? A reflection on the environmental sustainability of big data initiatives. *Sci. Eng. Ethics* **2020**, *26*, 1009–1030. [CrossRef]
22. European Commission. High-level expert group on artificial intelligence. In *Ethics Guidelines for Trustworthy AI*; European Commission: Brussels, Belgium, 2019. Available online: https://op.europa.eu/en/publication-detail/-/publication/d3988569-0434-11ea-8c1f-01aa75ed71a1 (accessed on 27 February 2022).
23. Van Wynsberghe, A. Sustainable AI: AI for sustainability and the sustainability of AI. *AI Ethics* **2021**, *1*, 213–218. [CrossRef]
24. Tamburrini, G. The AI carbon footprint and responsibilities of AI scientists. *Philosophies* **2022**, *7*, 4. [CrossRef]
25. World Commission on Environment and Development. *Our Common Future*; Oxford University Press: Oxford, UK, 1990.
26. Dobson, A. *Ustice and the Environment: Conceptions of Environmental Sustainability and Theories of Distributive Justice*; Oxford University Press: Oxford, UK, 1998.
27. Wagenaar, H. Interpretation and intention in policy analysis. In *Handbook of Public Policy Analysis: Theory, Politics, and Methods*; Fischer, F., Miller, G.J., Eds.; Routledge: New York, NY, USA, 2007.
28. Yanow, D. The Communication of policy meanings: Implementation as interpretation and text. *Policy Sci.* **1993**, *26*, 41–61. [CrossRef]
29. Yanow, D. *How Does a Policy Mean? Interpreting Policy and Organizational Actions*; Georgetown University Press: Washington, DC, USA, 1997.
30. Vucetich, J.A.; Nelson, M.P. Sustainability: Virtuous or Vulgar? *BioScience* **2010**, *60*, 539–544. [CrossRef]
31. Nelson, M.P.; Vucetich, J.A. Sustainability science: Ethical foundations and emerging challenges. *Nat. Educ. Knowl.* **2012**, *3*, 12.
32. Zagonari, F. Environmental sustainability is not worth pursuing unless it is achieved for ethical reasons. *Palgrave Commun.* **2020**, *6*, 108. [CrossRef]
33. Dalsgaard, S. The commensurability of carbon: Making value and money of climate change. *HAU J. Ethnogr. Theory* **2013**, *3*, 80–98. [CrossRef]
34. Blythe, J.; Silver, J.; Evans, L.; Armitage, D.; Bennett, N.J.; Moore, M.-L.; Morrison, T.H.; Brown, K. The dark side of transformation: Latent risks in contemporary sustainability discourse. *Antipode* **2018**, *50*, 1206–1223. [CrossRef]
35. Lélé, S.M. Sustainable development: A critical review. *World Dev.* **1991**, *19*, 607–621. [CrossRef]

36. Oermann, N.O.; Weinert, A. Sustainability ethics. In *Sustainability Science*; Heinrichs, H., Martens, P., Michelsen, G., Wiek, A., Eds.; Springer: Dordrecht, The Netherlands; Berlin/Heidelberg, Germany; New York, NY, USA; London, UK, 2016; pp. 175–192.
37. Shearman, R. The meaning and ethics of sustainability. *Environ. Manag.* **1990**, *14*, 1. [CrossRef]
38. Holmes, R. Justifying Sustainable Development: A Continuing Ethical Search. *Glob. Dialogue* **2002**, *4*, 103–113.
39. Vogt, M.; Weber, C. Current challenges to the concept of sustainability. *Glob. Sustain.* **2019**, *2*, e4. [CrossRef]
40. Saldana, J. *The Coding Manual for Qualitative Researchers*; Sage Publications: Thousand Oaks, CA, USA, 2013.
41. Braun, V.; Clarke, V. *Thematic Analysis: A Practical Guide*; SAGE Publications: Thousand Oaks, CA, USA, 2021.
42. Leavy, S. Gender bias in artificial intelligence: The need for diversity and gender theory in machine learning. In Proceedings of the ACM/IEEE 1st International Workshop on Gender Equality in Software Engineering, New York, NY, USA, 28 May 2018.
43. Emmet, D. Regulative ideals: Kant. In *The Role of the Unrealisable*; Palgrave Macmillan: London, UK, 1994.
44. Friedman, M. Regulative and constituative. *South. J. Philos.* **1992**, *30*, 73–102. [CrossRef]
45. Liu, R.; Gailhofer, P.; Gensch, C.-O.; Köhler, A.; Wolff, F. *Impacts of the Digital Transformation on the Environment and Sustainability: Issue Paper under Task 3 from the "Service Contract on Future EU Environment Policy"*; Öko-Institut for the European Commission: Freiburg, Germany, 2019. Available online: https://ec.europa.eu/environment/enveco/resource_efficiency/pdf/studies/issue_paper_digital_transformation_20191220_final.pdf (accessed on 27 February 2022).
46. Samuel, G.; Broekstra, R.; Gille, F.; Lucassen, A. Public trust and trustworthiness in biobanking: The need for more reflexivity. *Biopreserv. Biobank.* 2022, *ahead of print*. [CrossRef] [PubMed]
47. Available online: https://sdgs.un.org/goals (accessed on 27 February 2022).
48. Dauvergne, P. *AI in the Wild*; MIT Press: London, UK, 2020.
49. Reich, R. *Saving Capitalism: For the Many, Not the Few*; Icon Books: London, UK, 2017.
50. Hunt, D.F.; Bailey, J.; Lennox, B.R.; Crofts, M.; Vincent, C. Enhancing psychological safety in mental health services. *Int. J. Ment. Health Syst.* **2021**, *15*, 33. [CrossRef] [PubMed]