Title	Virtual consumption: A review of digitalization's “green” credentials
Author(s)	Hynes, Mike
Publication Date	2022-11-23
Publication Information	Hynes, Mike. (2022). Virtual consumption: A review of digitalization's “green” credentials. Frontiers in Sustainability(3:969329). doi:10.3389/frsus.2022.969329
Publisher	Frontiers Media
Link to publisher's version	https://doi.org/10.3389/frsus.2022.969329
Item record	http://hdl.handle.net/10379/17563
DOI	http://dx.doi.org/10.3389/frsus.2022.969329

TYPE Review
PUBLISHED 23 November 2022
DOI 10.3389/frsus.2022.969329

OPEN ACCESS

EDITED BY
Henrike Rau,
Ludwig Maximilian University of Munich, Germany

REVIEWED BY
Douglas Aghimien,
University of Johannesburg, South Africa
Sabine Hielscher,
University of Sussex, United Kingdom

*CORRESPONDENCE
Mike Hynes
mike.hynes@universityofgalway.ie

SPECIALTY SECTION
This article was submitted to Sustainable Consumption, a section of the journal Frontiers in Sustainability

RECEIVED 14 June 2022
ACCEPTED 07 November 2022
PUBLISHED 23 November 2022

CITATION
Hynes M (2022) Virtual consumption: A review of digitalization's "green" credentials. *Front. Sustain.* 3:969329. doi: 10.3389/frsus.2022.969329

Virtual consumption: A review of digitalization's "green" credentials

Mike Hynes*

School of Political Science and Sociology, University of Galway, Galway, Ireland

The unprecedented development, growth, and widespread pervasiveness of digital Information Communication Technologies (ICTs) have coincided with ever-increasing levels of consumption and the climate emergency. Digital ICTs, once lauded for their potential to dematerialize society, are now imposing additional burdens on the planet. The widespread consumption of personal electronics continues to grow at an enormous rate, while recycling of the scarce rare-earth minerals that are crucial to their development is negligible. As digital technologies become ubiquitous, the need for additional energy to power our ever-increasing number of digital devices and services must also keep pace. Moreover, despite their public veneer as progressives, digital tech companies are collaborating with fossil fuel companies to render oil and gas extraction more profitable and with greater speed, fuelling climate breakdown. Online social platforms are also being misused as podiums for dis/misinformation and falsehoods counter to the scientific consensus of anthropogenic climate change, allowing the digital tech sector to abdicate any social responsibility and denying the dire consequences of inaction. This review article explores the growing consumption demands and the ecological threat from digitalization and the digital tech sector: demands that will only intensify with our insatiable appetite for digital tech services and products. Such a review aims to draw closer attention to some ways such technology can be used to assist ecological research and conservation, but also to expand upon our understanding of the negative environmental aspects of a relentless push toward a Digital Society. In uncritically accepting Big Tech's virtuous credentials, we are choosing to ignore the immense power and influence they have over our lives, and the ways they may be propelling our environment toward collapse.

KEYWORDS

digitalization, consumption, climate change, Information Communications Technologies (ICT), Big Tech

Introduction

The development and ubiquitous public acceptance of digital Information Communications Technologies (ICTs) in contemporary society have been an incredible phenomenon, ushering in the Digital Age.[1] Such technologies now play a pivotal role in keeping us all more connected to family and friends, also allowing us to work more efficiently and competently—-at times, performed at a distance from traditional centrally located workplaces—-and in some cases helping to improve our health and overall quality of life. All these features and benefits of digital technology were brought into sharp focus throughout the recent global pandemic. The utility of many aspects of digital ICTs is now widely accepted, and it would be foolhardy to suggest otherwise. There continues to be significant optimism, and myth, around the development, aims, use, and diffusion of digital ICTs and, indeed, hope that such technologies can offer solutions in addressing critical issues related to (over)consumption, conservation, and for developing strategies that can mitigate the risks of further environmental harm (UNFCCC, 2021). However, the impetuous forward momentum of digitalization globally and its impacts on consumption and the climate is a double-edged sword, and the positive effects are not always unequivocal and absolute. With the speed of digital ICT innovation and development came an unconsciousness or blindness to adverse negative aspects of their impacts on society and the environment that have been under-investigated and under-acknowledged (Dwivedi et al., 2022). For example, Junior et al. (2018) suggest that digital tech is one of the least sustainable and most environmentally damaging sectors globally. The pervasive consumption of personal electronics—-in particular lightweight mobile digital devices such as smartphones, laptops, tablets, and wearable digital technologies—-is contributing to mounting environmental concern about the mining of the precious rare-earth materials and minerals needed to power these gadgets and the growing e-Waste that results once such devices are discarded (Ohene Opare and Mirkouei, 2021). Moreover, the obscured energy demands fuelling our voracious appetite for services run on these digital devices are now placing immense pressure on energy supplies, which is powering an even greater intensification in the burning of fossil fuels worldwide. Colossal data centres are now central to the Digital Age and are being built at an extraordinary rate globally to keep up with services demands (Statista, 2022b) leading to growing energy consumption. Digital innovations, such as Blockchain and crypto currencies, are consuming vast quantities of energy in their "mining," all of which, it is argued, remain heavily reliant on the burning of fossil fuel (Gundaboina et al., 2022). Meanwhile, the leading corporations of the digital tech sector are actively assisting and hastening fossil fuel extraction and amplifying climate change denial, contrary to their more enlightened public image and utterances.

There is now an increasing urgency to "shine a light into the darker corners of digitalization" and to highlight the societal, cultural, economic, and environmental challenges that have emerged and that need to be confronted (see Hynes, 2021). This review investigates the realities of our relentless push toward a "Digital Society"[2] in terms of the environment, conservation, and consumption: to highlight some positive ways digitalization is contributing to ecological good, but also draw attention to some growing environmental concerns related to the Digital Age. It is not an attempt to account for all such new digital technologies, innovations, and practices, but instead to consider and discuss the main ecological impacts and effects of digitalization, and how the digital tech sector broadly responds to such challenges. While there are increasing attempts to investigate and report on the economic, social, and political consequences of digitalization (for example: Runciman, 2018; Zuboff, 2019; Zhuravskaya et al., 2020; Fuchs, 2021; Herlo et al., 2021; Susskind, 2022), environmental, ecological and sustainability concerns related to the Digital Age have received less attention. With some exceptions (e.g., Hazas and Nathan, 2018; Efoui-Hess, 2019; McGovern, 2020) there continues to be a deficiency of academic literature on how genuine environmental protection and harm reduction can be incorporated into future digital technology development, innovation, and transformations (Feroz et al., 2021). The rationale for this review, therefore, is an attempt to bridge this gap and provide a broader and more holistic overview of the ways digitalization, and the industry itself, is impacting our environment and whether it should be understood as an environmental good actor or not. In the absence of a deeper understanding of the ways and means digitalization has embedded and normalized itself into our everyday lives, we become blind to the many ways it is affecting our quality of life and furthering climate breakdown.

1 For the purpose of this review, the Digital Age refers to the technologies and networked connectedness that has been made possible by the development and widespread use of microprocessors, memory chips and telecommunication circuits over the recent decades. These developments led to incredible growth in the use of computers in the workplace and in the home, largely beginning in the 1990, heralding what has become known as the Third Industrial Revolution or the Digital Age. This new age is often epitomised by the development and public availability of the World Wide Web in 1991.

2 The concept of the 'Digital Society' is an attempt to understand digital ICTs as having intentional social and political power, to mould a research and development agenda around such technologies, and inform discussions on policy, innovation and likely opportunities into the future. For a good overview of current research in this area, see the Internet Policy Review special section (Katzenbach and Bächle, 2019).

For this review, a broad exploration and examination of the current literature was conducted for several months—-February to June 2022—-in addition to the author's previous research experience and interest in the areas of digital ICTs and their societal and environmental impacts. An initial list of emerging technologies and environmental issues was established through the use of Google search using Google Chrome and the use of keywords: in the case of the positive effects "digital technology environmental good list," and in the case of the negative effects "digital technology environmental harm list." This online search aimed to select studies, research, reports, and articles that would best reflect the current literature and evidence, but some subjectivity must be acknowledged in this desktop online search. A list was drawn up of some key areas and concerns that require closer consideration and examination, a list that suggests some similarities across the various websites. An assessment and analysis of these listed areas and concerns were then undertaken. There was a considerable focus on the most up-to-date research and reports from some leading agencies and organizations tasked with investigating the positive contribution digital ICTs can have, but also the consequences and effects digitalization is having in terms of (over)consumption of resources and energy, and on the environment generally. In addition, there was particular attention given to some leading academics, social and environmental public commentators who are more critical of current digitalization pathways, and an investigation of the public debates and discourses from political arenas. The results were all used to identify, assess and communicate a more complete evaluation of the current state of digital ICTs, in terms of its present and potential future environmental attributes and credentials. It is argued that the narrative of almost unstoppable changes is already underway, driven by a technological determinism that this is affecting our economy, society, and the environment in various ways (Ström, 2019; Vogels et al., 2020; Sareen and Haarstad, 2021). There is danger in failing to recognize and discuss the harmful ecological outcomes of digitalization more destructive technologies and practices, which become societally embedded over time. But, with a clearer understanding of what is happening society can realize different pathways: we can find occasions to intervene, to resist, to organize and legislate, to plan, and to design our shared futures (Mitchell, 1996). Based on this overall review, possible ways to address these concerns will be presented. However, it is important to begin such a review on a positive note and to point to some of the encouraging contributions that digital ICTs have and are having, and potentially can have, on consumption, the environment, conservation efforts, and in alleviating various elements of the climate crisis.

Digitalization's positive contributions

The emergence of the Digital Age must be positioned within the wider context of one of the key challenges facing contemporary society. The evidence of anthropogenic climate change is now undeniable. One of the key conclusions of the most recent Intergovernmental Panel on Climate Change (IPCC) report on the subject is that it is now an "established fact" that humans are disproportionately responsible for the excessive greenhouse gas (GHG) emissions that have led to an intensification of extreme weather and climate events over the recent past (IPCC, 2022). The planet is now facing a three-pronged threat of climate change, pollution and excessive waste, and biodiversity loss, and policies and actions to address these are now time-critical. Well-designed and thoughtful initiatives leveraging the benefits of digital ICTs have the potential to be instrumental in helping positively change patterns of consumption and shape low-carbon pathways and futures, making us less vulnerable to risks (Stančič, 2012). In particular, digital ICTs can help with consumption and climate monitoring, energy efficiency strategies, approaches to mitigation and adaptation, and wildlife and biodiversity conservation efforts. Under the 2030 Development Agenda, the United Nations General Assembly identified the need to recognize and value the role that digital ICTs can play in engaging with its Sustainable Development Goals (SDG), and the opportunities this may present (Wu et al., 2018). This section investigates just a few of these digital ICTs opportunities and approaches that are being used to assist efforts at mitigating some of the worst effects of climate change, aiding conservation efforts, and preserving the biosphere for future generations. These have been selected based on their development and maturity, and their current availability and status as digital technologies applied to alleviate various aspects of environmental and ecological harm.

Monitoring, recording, capturing

The IPCC (2020) classified several recent digital technologies that it states can aid in the transition to net-zero emissions as mature and in the early stages of development and adoption. But some scientists now see the need for a novel new set of digital technologies that will be essential to comprehensively de-fossil fuel our entire energy systems (Minx et al., 2017). This set of new technologies is commonly referred to as "carbon management" and includes carbon capture, utilization, and storage (CCUS) technologies.[3] The term is manifest in the recently retitled Office of Fossil Energy and Carbon Management in the U.S. Department of Energy (Faber et al., 2021). As part of this set of approaches, Digital ICTs provide the unique ability to both effectively and efficiently collect and analyze important carbon emission information that

3 Although originally developed by NASA in the 1970s, such technologies are at varying levels of maturity but can be described as 'new' because of the immense increase in computing power made possible by digitalisation over the past few years.

enables us to better assess society's impacts on the environment. This information allows us to manage energy use and the production of both home and industrial greenhouse gases. Such technologies are used to investigate and manage the local and global environment and come under three general headings of observation, analysis, and the sharing of data. Digital ICTs contribution to carbon management is largely broken into three main categories: emission measuring and reporting, abatement, and carbon offsetting. Measuring encompasses the collection of CO_2 data emissions organized by type and geographical region. Abatement involves identifying the significant emission sources and attempting to apply some reduction measures. Carbon offsetting is considered the option of last resort and is a scheme whereby an organization, city, region, or indeed an individual, attempt to neutralize and compensate for their emissions by investing in other projects or initiatives that reduce or stores carbon. Such offsetting is related to a wide range of environmentally friendly projects such as providing renewable energy sources to protect the rainforests, and the offsetting is dependent on a system of credits that pay for an organization's carbon emissions. Digital technologies help gather data from various sources and metering instruments and allow for more efficient reporting and analyses on such data, and in some instances allow systems to optimize energy use.

Conservation efforts

Digital ICTs hold the potential to help with conservation management efforts and to assist conservationists in better understanding and addressing acute ecological challenges, helping protect biodiversity and endangered species globally, and communicating the damage inflicted upon the biosphere from the worst effects of anthropogenic climate change. A report for *Wildlabs* (Speaker et al., 2021) found that Artificial Intelligence (AI)[4] was one of the leading emerging digital technologies that could considerably aid conservation efforts. Using already established technologies such as satellite imaging, audio recordings, and location-specific camera footage, the report stated that AI could be used to identify rare and endangered species from the thousands of photographs gathered from such technologies or to determine a specific animal class from audio field recordings. Such technologies hold the potential to lessen the laborious manual work required to gather such essential conservation data from large pools of images and audio and to determine a specific fit. Digital ICTs also increasingly influence the ways that the public recognizes, considers, and engages with nature and, in some instances, can be used to re-engage and re-connect young people with their natural environment (Altrudi, 2021). These digital communication mediums have been acclaimed by conservationists because they promise more and faster data processing and actionable information. They promise new and novel communication means, improved information access, and stimulating visual representations: all of which go to make up new powerful decision-making support systems (Arts et al., 2015; van der Wal and Arts, 2015). Other uses of digital ICTs in conservation efforts include the use of "smart" collars to help track and conserve wildlife (Willoughby, 2017), better mapping and visualization through the use of platforms like Google Earth (Beresford et al., 2020), remote mapping and the monitoring of wildlife and biodiversity (Wich and Koh, 2018), the use of genomic approaches to wildlife conservation and management (Hohenlohe et al., 2021), and the use of predictive analytics software in conservation, helping researchers pinpoint where endangered animals are geographically located and their specific movement patterns, and even how they form into their various social groups (IndustryWired, 2022).

4 The term AI is frequently used to describe machines that mimic and display human behaviours and human cognitive abilities and skills. Because of the enormous increase in computing power brought about by digitalisation, AI research and improvements has been able to make great leaps forward in the past two decades and, thus, in this review AI is viewed under the suites of developments made possible by digitalisation.

Tracking emissions from space

In addition to digital ICTs supporting conservation efforts, a new generation of satellites, powered by digitalization innovation and development and set to launch in 2023, will soon be able to track emissions of the potent climate-warming gas methane and assist in emission reduction goals. The first of these new higher resolution-monitoring satellites will launch next year, delivering data that will provide near-global coverage of plumes of methane emissions directly back to research centers on earth. Speaking to reporters for *The Guardian*, Ilissa Ocko, a climate scientist for the Environmental Defense Fund's (EDF) MethaneSat, suggested that these satellites will provide information on the levels of emissions coming from particular areas of the planet, which then can be aggregated for specific countries so that we are more informed about what actual baseline emissions currently exist (Timperley, 2022). These follow on from previous satellites which sent back images revealing that the bulk of the 1,800 biggest methane sources come from just six major fossil fuel-producing countries: Turkmenistan, the Russian Republic, the United States, Iran, Kazakhstan, and Algeria (Lauvaux et al., 2022). Methane is the second-largest contributor to climate change after CO_2, but until recently had received much less attention. The Intergovernmental Panel on Climate Change reported that anthropogenic methane is responsible for about a quarter of the 1.1^{C} warming that is being witnessed today, and tracking such emissions will have a significant impact on whether the world manages to keep the global temperature rise below 1.5^{C}

(IPCC, 2022). Previously, NASA's OCO-2 satellite was launched in 2014 and was developed to observe carbon dioxide levels in the atmosphere (Taylor et al., 2016). The Paris Agreement[5] established a transparency framework for CO_2 emissions, and researchers have now developed a model that can calculate individual countries' emissions from the burning of fossil fuels from observations from space (Kaminski et al., 2022). Such advancements in digital ICTs have enabled new efficiencies, depth, and levels of measurement and analysis of the data returned from these satellites, and such information can assist with averting the most severe impacts of air pollution and climate change, which requires an understanding of the sources of such emissions.

In the home

Home Energy Management Systems (HEMS) provide beneficial feedback on household energy consumption and usage through a host of smart home devices and features. Such systems normally provide a connection to cloud-based data storage, are accessible through a smartphone or digital device app, rely on user intervention to manage energy consumption in response to alerts about usage, generation, and or pricing information, and are designed to better support key decision-making for sustainable household energy consumption (Shaw-Williams, 2020). The necessary usage, generation, and pricing data emanate from the Internet of Things (IoT), a network of linked physical objects, "things," or nodes that are interconnected and that communicate specific data for analyses. These include mobile or fixed digital devices, computers, household appliances and machines, and may even include people or animals that are embedded with electronic sensors or software (Gillis, 2022). Each of these nodes possesses unique identifiers and has the function and ability to transfer data instantaneously across the network with minimal human-to-human or human-to-computer interaction or interventions. In 2019, of the 17% of gross energy consumption across the European Union, household energy consumption accounted for some 26% (Eurostat, 2021). In terms of energy consumption and efficiency, such new digital technologies applied to a variety of smart home devices and appliances have the potential to reduce overall energy demand and introduce efficiencies into the domestic sector (European Commission, 2015). Energy efficiency in homes and other buildings is considered one of the most fundamental objectives for supporting and promoting international energy sustainability, and this challenge has motivated recent research in the design of HEMS based on sensors that analyze how energy is consumed (Moletsane et al., 2018). The term *smart home* refers to HEMS being aware of the state of its devices, which is done through the use of digital ICTs and their connection to the wider internet (Mandula et al., 2015). Smart homes usually comprise smart devices and appliances, smart metering, and home automation, and often entail varying levels of tariffs to the consumer. Smart metering makes it feasible to amass and deliver energy consumption data and information to homeowners and Utility companies in real time, and smart devices and appliances can respond spontaneously to exterior signals optimally with the help of home automation systems (Paetz et al., 2012).

At the micro or grassroots level, individuals can make personal contributions to reducing consumption in a meaningful way through their actions prompted by information and feedback obtained from countless available digital apps. D'Arco and Marino (2022) revealed a positive and substantial link between the awareness of consequences, an acknowledgment of responsibility, individual norms, and environmental citizenship behavior in both the private and public spheres. Their study, however, also suggested that the use of sustainability apps, or eco-apps, had only a moderating effect on the predictors of environmental citizenship behaviors. The consumers' perception and awareness of eco-products have the maximum effect in directing their environmental concerns into purchase intent, or in reducing consumption generally (Hojnik et al., 2019). Additional research established a complex relationship between the individual's earlier environmental understanding and knowledge and the use of green labeling that influence attitudes toward sustainable products (Cerri et al., 2018). Ethical features of the production process were also important forecasters of consumer attitudes toward sustainable or eco products, contrary to previous understanding. Eco-apps that promote resource sharing, recycling, making greener product and fashion choices, helping to fight food waste, and sharing the positive changes individuals are making within like-minded communities, all indicate the utility of using mobile digital services to engage individuals in sustainable consumption practices and in tackling environmental issues (Balińska et al., 2021).

Working from home

Another promising way that digital ICTs can contribute to energy consumption efficiency, which underwent an inevitable and significant rise during the recent pandemic, is the practice of working from home. Working from home (also known as teleworking, telecommuting, or eWork) can potentially lessen, or even eliminate, the obligation to commute by private car daily to and from a person's place of work, and it has been lauded by

5 Adopted by some 196 countries at COP 21 in December 2015 and coming into force on the 4th November 2016, the Paris Agreement is a legally binding treaty that set controls on global emissions for all international signatories. The overall aim of the Paris Agreement is to limit global warming to well below 2 degrees Celsius over the coming years, preferably 1.5 degrees Celsius.

some policy- and decision-makers as a valuable way to decrease the overall "unsustainable consumption of distance" (Hynes, 2013). Drawing on a survey of some 10,000 Americans aged 20–64 years, Barrero et al. (2020) revealed that the pandemic necessitated a significant shift to working from home, reducing commuting time among American workers by more than 60 million h per workday. A systematic review of the energy impacts of teleworking found that 26 out of 39 studies revealed that the shift to teleworking had reduced overall energy use: only eight studies suggest that teleworking increased or had no impact on such consumption (Hook et al., 2020). This review incorporated the energy savings from reduced commuting to and from work, and the indirect impacts associated with changes in home energy consumption and non-work travel. Analyses of commuter trends and labor market data from the International Energy Agency (IEA) during the pandemic established that if every person capable of working from home were to do so for just 1 day a week, it could have a saving of ∼1% of global oil consumption for road transportation per annum (Crow and Millot, 2020). Factoring in the inevitable rise working from home would have in overall household energy consumption, the impact on global CO_2 emissions would see a yearly decline of 24 million tons (Mt), which is equivalent to the majority of Greater London's annual CO_2 emissions. However, it is argued that while working from home may well help to lessen transport-related carbon emissions, the definitive size of such reductions remains highly susceptible to rebound effects[6] (Bachelet et al., 2021).

Matters of growing environmental concern

To avoid the enormous human and social costs that will inevitably arise from unchecked climate change, all sectors of the global economy, including digital ICTs, must endeavor to maintain or reduce their greenhouse gas emissions in line with those levels established in the Paris Agreement. Global digital ICT consumption is largely made up of three significant sectors: end-user equipment and related services, data centers, and networks. In light of the concerted efforts to reduce greenhouse gas emissions after the signing of the Paris Agreement, ICTs have received limited attention and scrutiny as a major contributor to global emissions and are, indeed, often lauded and promoted for assisting efficiencies that reduce other industry sector's carbon footprints (IEA, 2017). However, the growth in digital ICTs has coincided with steady growth in the size of our overall global carbon footprint. Several studies before 2015 showed consistent increases in the carbon footprint of digital ICTs and, even without considering the full life cycle emissions, the trend line showed a 40% increase from 2002 to 2012 (Ritchie et al., 2020). But digital ICTs and the Big Tech sector could be responsible for an even greater portion of worldwide emissions than previously stated, and these will continue to increase considerably unless action is taken, a new study highlighted (Freitag et al., 2021). This study examined peer-reviewed estimates of digital ICT emissions, which put the industry's share at 1.8–2.8% of overall levels. It revealed marked differences in emissions and arguments about the underlying assumptions behind the peer-reviewed studies, deliberations that may well suggest that global emissions from the digital tech sector are even higher than stated. All the analysts agreed that digital ICT emissions will not decrease without major collaborative industry and political attention and responsiveness, and they provided reasons for anticipating that emissions from the sector will increase over time without real and concerted action. The energy footprint of ICTs is still growing due to broader demands in a range of economic sectors (Makonin et al., 2022), even as the energy consumption of individual devices is reducing. Large installations of digital ICTs for the implementation of energy Smart Grids and e-services will further increase emissions. Belkhir and Elmeligi (2018) suggest that, without immediate action, digital ICT emissions could well increase from about 1% to 1.6% in 2007 to surpass 14% of the 2016-level global greenhouse gas emissions by the year 2040. This would account for more than half of the current comparative emissions from the transportation sector. Freitag et al. (2021) argue that while the tech sector offers ways and opportunities to assist greenhouse gas emission reduction in other sectors, the evidence does not support their ability to achieve the prolonged major carbon savings in their industry that is required by 2050. This particular section of the review will look more closely at some of the more prominent areas, as revealed in the online search, in which the growth in digital ICTs continues to accelerate unsustainable energy and resource consumption leading to continuing climate breakdown and some significant social costs.

The relentless consumption of electronic devices

The emergence of the Digital Age has coincided with an enormous upsurge in the consumption of small, portable digital electronic devices and gadgets. The consumer electronics market was valued at over US$ 1.7 trillion in 2016 and is expected to surpass US$ 3.8 trillion by 2024 (Coherent Market Insight, 2022). Products traditionally categorized as consumer electronics are devices such as tablets, smartphones, laptops, computers, game consoles, digital televisions and

6 Also known as the Jevons Paradox, the rebound effect proposes that the more efficient technologies become the greater use of a resource. This, over time, tends to reduce or eliminate such efficiency gains. It is a term named after William Stanley Jevons who, in his book the Coal Question, wrote about such anomalies in the coal industry at the end of the 19th century.

cameras, wearable technologies such as watches, and other home or smart home devices and products. The Covid-19 pandemic and resulting measures implemented across societies to restrict the spread of the virus ignited a substantial and sustained surge in sales in many segments of the consumer electronics market throughout 2020 and 2021 (Upadhyay and Watkins, 2021; Stewart and Crossan, 2022). These increases in sales were mainly driven by the absence of out-of-home entertainment opportunities and the pivot to working and studying from home for many individuals and families. Digital Consumer Innovation (DCI) designates consumers purchasing and acquiring digital products or services in the fields of food, transport, household goods, and energy, which influence a person's consumption habits or lifestyle and, thus, transform conventional consumption patterns (Lyons et al., 2018). Such change can be complex and diverse, given such a sociotechnical system, so the benefits in terms of carbon emission savings brought about by DCI can be erratic and ambiguous. People from different socio-economic backgrounds with mixed understandings, acquisition abilities, and usage needs, also differ in their approaches, a construct termed "digital inequality" (Zilian and Zilian, 2020). But many people across the globe are now connected through the use of mobile digital communication technologies and devices, although again not always equally (Silver, 2019). Most of a smartphone's energy cost comes from the production process. In terms of energy use, building a smartphone accounts for nearly 85–95% of its annual carbon footprint because engineering its electronics and mining for the rare-earth minerals and metals that go into their assembly is energy-intensive (Patel, 2018). Analysis has shown that smartphone emissions grew from 17 to 125 megatons of carbon dioxide equivalent between 2010 and 2020—-an increase from 4 to 11% of overall digital ICT emissions—-and this is largely driven by the 1.5–2.5 years that a smartphone is used on average (Pasternack, 2020). Very few of these personal digital communication devices are recycled (Statista, 2021), an issue that will now be looked at in more detail shortly. However, before discussing the issues of recycling and e-waste, the mining of rare-earth minerals and metals to fuel the extraordinary consumption of mobile digital ICT devices needs closer attention.

Mining for precious metals to power our devices

Smartphones, and other high-technology digital ICT devices, are manufactured using mineral commodities, more than half of which are mined and semi-processed materials from various regions of the world. This is leading to a booming international mining industry and trade specifically targeted at mining for rare-earth minerals and metals that go into the manufacture of our digital devices.[7] Mining for such rare-earth components remains extremely problematic and damaging to local mining communities. In addition to contaminating the air, the process also damages ecosystems and generates "tailing," which is the toxic and unwanted by-products that seep into the soil and water sources during the mining process. These rejected minerals and rocks release toxic metals such as arsenic and mercury which damage aquatic wildlife that rely on a clear clean water supply (Tayebi-Khorami et al., 2019). Moreover, while some of these minerals and metals can be found and mined safely and ethically in developed countries, most are located in countries fraught with conflict and secrecy and often mined in environmentally damaging ways. For example, smartphones predominantly run on lithium-ion batteries. This material is extracted from salt lakes, a significant potion that comes from the so-called "lithium triangle" that includes countries in South America such as Chile, Bolivia, and Argentina (Ahmad, 2020). In these regions, mining companies negotiate with the indigenous communities who inhabit these areas. Heredia et al. (2020) reported that these communities agree that mining, and its associated activities, done without considering sustainable development approaches, damage their natural local ecosystems and the special relationship they have with their lands. Specifically, the amount of water utilized by lithium mining projects was of particular concern to indigenous representatives: both the extraction of brine and the water needed to process the brine.

Rare-earth deposits can be found on all continents of the planet. However, China produces more than 90% of all globally used rare-earth materials, which has led other regions and countries, such as Europe, America, Australia, and Japan, to express growing concern about the supply chain of such materials, and the world's collective and mounting dependence on China for such resources (Jaroni et al., 2019). About half of that output is from the city of Baotou alone, and most of the rare-earths processed are extracted in Bayan Obo, a mining district some 120 km north of the city in the Gobi Desert. A report in *The Guardian* revealed that ore is often contaminated with radioactive materials such as thorium, and the separation process requires huge amounts of carcinogenic toxins such as sulfates, ammonia, and hydrochloric acid (Kaiman, 2014). Almost 2,000 ton of toxic waste is produced in processing just one ton of rare-earths, and Baotou's operations generate nearly 10 million tons of wastewater per year, much of which is thrust into tailing dams like the one 12 km west of the city at Wang's village. Zhang et al. (2022) suggested that the environmental costs of rare-earth exports are greater than the economic benefits that accrue. Foreign consumption contributes more than half of the associated environmental costs, with rare-earths

7 For more information about the minerals and metals that are assembled and used to make smartphones, see https://pubs.usgs.gov/gip/0167/gip167.pdf.

accounting for nearly 60% of the external consumption-induced environmental costs. This essentially means a convenient transfer of the negative impacts and costs of mining such materials from overseas countries back to mainland China. Illegal mining and processing of such materials inside China and their smuggling out of the country are damaging the Chinese mining industry while only the downstream industries are profitable, at the expense of the localized environment (Packey and Kingsnorth, 2016). This legacy of environmental damage, due to mining and processing activities, has raised social concerns and the pollution problem due to lax legislation that is now costing China billions of dollars to correct (Barakos et al., 2018). Further mining intensification threats are on the horizon. Electric vehicles are now strongly positioned and politically supported as green technologies to reduce CO_2 emissions and help abate some of the challenges of climate change emanating from the transport sector. But their effective market dissemination will greatly increase demand for specific metals such as lithium and cobalt for car batteries, as well as for other rare-earth minerals and metals for the magnets used in electric motors (Langkau and Erdmann, 2021).

Cobalt is a crucial mineral in lithium-ion batteries used in the development of smartphones, and the majority of the international reserve of cobalt originates from the Democratic Republic of Congo in Central Africa. More than 70% of the world's cobalt comes from the Democratic Republic of the Congo, 15–30% of which is produced by artisanal and small-scale mining (Baumann-Pauly, 2020). Consequently, there are some significant ethical issues in cobalt mining, including concerns about child labor and environmental and ecological damage. The region is further beset by widespread corruption and conflict. Significant problems and concerns have been documented by human rights organizations over the recent past, and these human rights threats were especially high in artisanal mining operations. Amnesty International issued two reports in 2016 and 2017 that highlighted mining conditions in the region, and these reports exposed companies that were sourcing materials from artisanal mines that were enabling and protecting child labor and other harmful business practices in their supply chain (Amnesty International, 2016, 2017). Researchers at KU Leuven (Belgium) and the University of Lubumbashi reported that cobalt mining takes a severe toll on the environment and the individual *creuseurs*[8] that work in the mines (Banza Lubaba Nkulu et al., 2018). The study revealed much higher levels of cobalt in the urine and blood of people living in these artisanal cobalt mine communities than people living in an adjacent control area. They found that industrial mining and metal processing at this level and scale has led to significant pollution and ecological damage in the region, and they produced empirical evidence that the artisanal extraction of cobalt that exists in the Democratic Republic of the Congo was causing general toxic harm to exposed peoples and communities.

Recycling and e-waste

The enormous consumption and rapid obsolescence of digital electronics and devices have not only led to growing concerns about resource consumption and depletion but also end-of-life electronic waste, or e-waste, management (Hussain, 2021). An extensive array of goods can be classified as electrical and electronic equipment. Digital ICTs equipment such as personal computers and associated peripherals, game consoles, mobile and smartphones, and other common electronic devices such as video and audio equipment, personal tablets, portable digital assistants (PDAs), MP3 players, and electrical tools, all fall under such category. In addition, numerous everyday items that could previously be considered electrical goods, such as washing machines and dryers, refrigerators, and dishwashers, are now described as "electronic" items because of the installed programmable microprocessors that help run such appliances. Beginning in the late 1980's, hazardous waste has been frequently transported to less developed nations and regions of the world (Akpan and Inyang, 2017). With the advent of computing and the emergence of the Digital Age, such hazardous waste often included e-waste. But growing opposition to such practices led to more stringent laws in developed countries, leading to an escalation in the costs of such waste management (UNEP, 2010). A succession of policies, regulations, and guidelines have since been developed and implemented at the regional, national, and global levels to stimulate and support reuse and recycling, as well as efforts at reducing the toxic raw materials that emanate from such hazardous waste. Despite such oversight and regulation, however, e-waste remains ineptly managed as demonstrated by the small numbers of regulated recycling centers internationally, the continuing illegal shipments of such waste to less developed countries, and evidential human health issues and ecological damage that still occurs (Bakhiyi et al., 2018). The *2020 Global E-Waste Monitor Report* (Forti et al., 2020) revealed that, in the year 2019, the total weight of e-waste was around 53.6 million metric tons of which only a mere 17.4% were appropriately collected and recycled: the remaining 82.6% were not accounted for. The report predictions for global e-waste projects are to climb to 74.7 million metric tons by the year 2030 and digital ICT devices and products contribute significantly to these global streams of hazardous e-waste. Much of this waste is still destined for under-developed nations and regions that lack the statutes, and policies, have social, economic, and cultural barriers, lack the technology and the appropriate treatment facilities to deal with such materials, and are effectively the dumping ground for such waste (Gollakota et al., 2020).

8 The French word creuseur means to dig, to dig a hole in, to hollow out, or to go in deeply. Creuseurs are the ' artisanal diggers' who work in the cobalt mines, often by hand and in poor conditions.

According to the World Economic Forum, only around 20% of e-waste is recycled globally (WEF, 2019): even though a host of complex components and materials such as iron, gold, and aluminum are discovered in such waste (Hsu et al., 2021). Although many arrangements have been developed and employed globally to manage e-waste correctly, most end up in landfill facilitates, incinerated, shipped to the less developed regions of the world, or managed and processed by the informal waste sector (Ilankoon et al., 2018). The informal management of e-waste has led to, in some cases, unlawful shipments of such waste and the exploitation of developing countries that do not have adequate rigorous safety and environmental regulations in place. Conversely, this informal waste sector has also provided some necessary income and employment for people and communities in less developed regions. Nevertheless, these workers, nearby populations, and especially children living in or near such informal e-waste facilities, are being regularly exposed to unsafe and dangerous elements and compounds that can affect cognitive function and intensify the risk of numerous diseases such as respiratory problems and cancers (Lebbie et al., 2021). Discarded and unwanted mobile and smartphones are currently one of the fastest-growing global waste streams and, although the potential for recycling such devices is well-developed and known, present recycling rates remain low (Gu et al., 2019). A worldwide accumulation of rejected but not yet redundant smartphones is highlighted in an index of some 25 countries, which analyses existing reuse and recycling levels (rebuy, 2021). This data indicated that some nations have more redundant or discarded phones hoarded in homes than they have people living in the country. It must also be stated that suppliers and providers of digital mobile devices, like smartphones, strongly influence whether such devices can be repaired and how long they last through their design processes and their business models and offers. Customer behavior is, therefore, directed and controlled by the business models of companies providing such devices and services. This makes corporate players key drivers of e-waste production and the resulting low recycling rates (Suckling and Lee, 2015). Cheng et al. (2020) found that subjective norms, attitude, and perceived behavior control positively influence a person's intention to recycle a mobile phone, and exhibiting environmental concerns will foster their environmentally responsible behavior, which further reinforces their recycling behavior. The recycling of e-waste in general needs to be intensified because mining the planet for scarce minerals and rare-earth metals to make new smartphones, devices and gadgets is unsustainable, according to scientists from the Royal Society of Chemistry (RSC, 2022). They estimated that, in 2021 alone, the world's mountain of discarded electronics weighed nearly 57 million tons, more than the Great Wall of China. They suggest a global effort to mine existing waste facilities for discarded materials rather than mining the earth for original deposits.

Data centres

Data is critical to providing the products and services of the Digital Age, leading to the growth in the storage of large amounts of consumer, personal and organizational data. Social media platforms, music and video streaming, big data, AI, crypto currencies, and the digitalization of many business and production flows are all leading to more and more data being stored and processed in giant data centres. There are burgeoning numbers of data centres being built across the globe to hold these vast stores of data, inevitably increasing energy consumption and demands. The greatest share of direct energy usage in such facilitates is taken by servers and cooling systems, with additional demand stemming from storage drives and network devices. It is estimated that 0.3% of global carbon emissions currently come from the data centre sector, but that a significant upward trend will continue over the foreseeable future (Jones, 2018). In the absence of increases in efficiency, almost 20% of all electricity will be needed to power the digital ICT sector—-accounting for up to 5.5% of the world's carbon emissions by 2025—-which is more than any country except the US, China, and India (Andrae, 2017). A review of various studies on the energy consumption of data centres found greater or smaller increases but, notwithstanding this uncertainty and variation, a further significant increase in the energy consumption of data centres seems likely (Hintemann and Hinterholzer, 2019).[9] The industry is responding: although the levels of computing in data centres more than quintupled between 2010 and 2018, the amount of energy consumed grew only six percent during that period due largely to improvements in energy efficiency (Masanet et al., 2020).[10] However, despite pledges made by both Google and Facebook to achieve carbon neutrality in their new generation hyperscale data centres, technological and policy instruments for decreasing or neutralizing carbon emissions in the sector have not been fully and systematically examined (Cao et al., 2022).

Although data centres are found in most regions of the world, new hyperscale data centres are impacting greatly on local power grids and can require upwards of 100–150 MW and

9 Expects differ on the energy consumption and demands because there are no official figures for data centres and many operators are reluctant to provide such information, quoting concerns over competition and security. Researchers, therefore, must estimate the real energy consumption levels by looking at sales figures for servers or estimates from surveys (Jungblut, 2019).

10 The first generation data centres, which were often inefficient and were operated by banks and others in the financial sector, are now being replaced by newer larger centres and facilities built and managed by the digital tech sector's leading corporations such as Google, Microsoft and Amazon. This may account for the slow rate of growth in energy consumption in the data centre industry.

consume hundreds of GWh of electricity on an annual basis (Kamiya and Kvarnström, 2019). In small countries like Ireland with a growing data centre market, they are quickly becoming a major source of energy demand. Electricity consumed by data centres in Ireland jumped by 144% between 2015 and 2020, according to figures supplied by the country's Central Statistics Office (CSO, 2022). Over the same period, the percentage of electricity consumed by these centres rose from 5 to 11% of overall usage, and these centres are expected to account for 27% of all electricity demand in the country by 2028. There are now 71 operational data centres on the island of Ireland, most concentrated around the Dublin region (Datacenters, 2022), with several others in the planning stage. The Oireachtas Climate Committee[11] heard that the capital city of Dublin alone has become the largest data centre hub in Europe, accounting for nearly a quarter of the overall European industry market share by the end of 2018 (O'Regan, 2021). Ireland, however, is now facing a serious challenge with the security of its energy supply, in part because of this increased energy consumption from data centres. The recent war in Ukraine and the resultant worldwide energy crisis will most likely bring such consumption into sharper focus and attention during the colder winter months ahead.

What is driving data centre growth?

Demand for data centre services is driven by the increasing volume of internet users worldwide, while new technology, practices, and information services hasten this demand. Making calls from our devices and sending and receiving short messages do not represent the greatest part of our carbon footprint, but the energy needed to sustain our growing demands to remain constantly connected does add up. Regular calls and messaging through mobile data generate about 70 kg of CO_2, while as much as 0.3 g of CO_2 per spam email and 50 g of CO_2 per email with an attachment are common (Berners-Lee, 2020). According to Statista (2022a), spam accounted for over 45% of all e-mails sent in December 2021. Watching about half an hour of Netflix generates 1.6 kg of CO_2, the equivalent of driving 4 miles. Overall, Netflix streaming services consume ~370 Terawatt hours (TWh) per annum, which is 1.8 times larger than the collective figure for data centres globally, at present (Kamiya, 2020b). According to *The Shift Project*, 80% of the combined data flows through the internet takes the form of moving images, and the average CO_2 emissions of streaming online video are more than 300 million tons per year, based on 2018 measurements (Ferreboeuf et al., 2019). Music streaming is also a significant contributor with emissions from the recorded music industry in America to be estimated at between 200 million kg to over 350 million kg in 2016, double that of the 157 million kilograms emitted in the manufacture and production of CDs (Brennan and Archibald, 2019). There are debates over exact numbers (Kamiya, 2020a) but the concrete figure for such emissions is challenging to establish because these depend heavily on the type of output device, the network connection and the resolution, and the fact that impacts are distributed across many different sources and regions.

There are currently upwards of 2,500 different crypto currencies being traded on the exchange market resulting in an ever-increasing carbon footprint as such consumption is needed in the mining process, storage, and transaction validation by their various networks (Huynh et al., 2022). Most crypto currencies consume large amounts of energy in their creation or mining, the best example of which is Bitcoin.[12] Cambridge University's Bitcoin electricity consumption index claims that internationally Bitcoin mining alone consumes 130.27 TWh of electricity per annum (CCAF, 2022): a level of consumption that is above countries like Argentina (124 TWh), Norway (123 TWh) and the Netherlands (111 TWh) (The Enerdata Yearbook, 2021). Most academic studies have focused almost exclusively on Bitcoin and principally on externalities resulting from the energy consumption during the mining process, but understudied crypto currencies add almost 50% on top of Bitcoin's energy consumption, which is leading to calls for a more holistic understanding of the environmental impacts of crypto currencies and Blockchain applications in general (Gallersdörfer et al., 2020). Worryingly, Mora et al. (2018) suggest that global temperature could increase by 20c by 2034 if nothing changes in the way technology are used in the creation and storage of crypto currencies. Digitalization's growing appetite for energy will further be driven by the growth in smart technologies, such as those in the home, in industry, and in our increasingly digitalized cities and towns.

More disturbing conduct and concerns

What is the digital tech sector doing to negate the increases in energy consumption brought about by the relentless push toward a Digital Society, and is it living up to its image as a progressive and enlightened industry of the 21st century? While the sector's rhetoric professes to believe in and promote the scientific consensus of climate change, their actions belie a

11 The Oireachtas is the bicameral parliament of Ireland and an Oireachtas committee is a group of members of the Oireachtas chosen by one or both Houses to consider a certain subject, in this particular case climate change.

12 Cryptocurrencies such as Bitcoin are generated or mined by high-end computing power brought to bear to decipher complicated mathematical equations and puzzles. Individuals are rewarded largely based on the amount of computing power they use in solving these problems and the entire process is highly energy intensive.

more troubling position. There is growing evidence that most of the major players in the digital tech sector are tendering their extensive digital ICT experience and knowledge to assist the fossil fuel industry extract oil and gas at much greater rates and with increased efficiency and haste than was possible in the past. A Greenpeace report, *Oil in the Cloud: How Tech Companies are Helping Big Oil Profit from Climate Destruction*, detailed how the digital tech industry was facilitating oil companies to uncover, extract, refine, and distribute oil and gas at a greater pace than heretofore (Donaghy et al., 2019). Amazon,[13] Google,[14] and Microsoft[15] had all undermined their climate pledges and commitments by signing lucrative contracts for their cloud computing services and other AI technologies with oil and gas companies. The carbon emissions from these very profitable agreements are often not stated in the tech companies' carbon reporting, thus concealing the impacts they are having on the changing climate (Stackl, 2020). As these international fossil fuel companies secretively plan large numbers of "carbon bomb" oil and gas projects that would push the climate past globally agreed on temperature limits,[16] the tech sector may well be key to the success of their ambition to supercharge the climate crisis. But, it is more than Big Tech's support for faster fossil fuel extraction: they are also using their immense financial muscle, power, and political weight in ways that undermine the seriousness of the climate emergency. The tech giants Alphabet (Google's parent company), Apple, Facebook, Amazon, and Microsoft spent ∼\$65 m in lobbying in 2020, yet only about 6% of their lobbying activities were related to climate policy and environmental protection. This is according to an analysis that tracked companies' self-reported lobbying on federal legislation (InfluenceMap, 2021) which reveals that despite vigorous climate statements and commitments from the tech sector, they are not purposefully using their substantial financial resources and influence over governments and regional policies in support of necessary climate action.

Meanwhile, many of the mainstream social media platforms are being used by the fossil fuel industry and malevolently by nefarious individuals and organizations to undermine the scientific consensus of climate change. A recent report written jointly by Friends of the Earth, Avaaz, and Greenpeace (2022) claims that for many decades now, the fossil fuel industry has spent millions of dollars on spreading climate dis/misinformation[17] on and offline to push public polarization, and slow and stop the action to tackle the climate crisis. The report states that previous research has shown that much of the climate dis/misinformation on social media platforms is spread by just a few actors, frequently with vested political and economic affiliations and interests. Such dis/misinformation is then amplified and extended by social media recommendation algorithms, which are specifically designed to maximize human attention and corporate revenue. Decades of such dis/misinformation on fossil fuels' impacts on the climate has halted real and genuine progress on U.S. climate action and policy, for example (Pierre and Neuman, 2021). It is also now widely recognized and accepted that social media platforms have made the circulation of dis/misinformation both simpler and quicker leading to increased climate change litigation (Setzer and Higham, 2021), and many find it difficult to distinguish outright lies from fact (Urakami et al., 2022). According to a recent report from the campaign group Avaaz, YouTube, which is part of the Alphabet suit of companies, has been "actively promoting" videos containing dis/misinformation about climate change: this is despite new policy changes at the company anticipated to shift users away from toxic content, material and conspiracy theories (Avaaz, 2020). The report found that advertisements for some of the world's most trusted brands—-including household names like Warner Bros, L'Oréal, Samsung, Decathlon, Danone, and Carrefourwere—-were found on climate dis/misinformation videos, and that about one in five ads were actually from ethical brands or green organizations including WWF, Greenpeace, and Save the Children.

The spread of dis/misinformation is interwoven with numerous on and offline social processes, one of which is

13 Amazon has become a significant player in the oil industry marketing its established and extensive cloud services to oil and gas companies, which allows these companies enhance and optimise fossil fuel extraction and production, and improve overall profitability (see https://oilprice.com/Energy/Energy-General/Why-Amazon-Is-Suddenly-Courting-Big-Oil.html).

14 It was reported that in 2018 Google started an oil, gas, and energy division (see https://gizmodo.com/how-google-microsoft-and-big-tech-are-automating-the-1832790799), although after the release of the Greenpeace Reports it pledged to stop building customised AI tools that assist oil and gas companies (see https://www.cnbc.com/2020/05/20/google-ai-greenpeace-oil-gas.html).

15 Petrobras and Shell recently announced collaboration with Microsoft (see https://www.energyvoice.com/coronavirus/260017/brazil-petrobras-microsoft/).

16 A recent *Guardian* investigation identified that the world's largest fossil fuel companies have planned some 195 'carbon bomb' projects that have the potential to each emit almost 1 billion tonnes of CO^2 into the atmosphere. It revealed that some 60% of such projects are already under way, which has significant consequences for limiting global emissions to 1.5 degrees Celsius. The investigation contended that, only just a few months after the Cop26 climate summit in Glasgow, countries such as America, Canada and Australia were among those with the most damaging oil and gas projects in development (Carrington and Taylor, 2022).

17 The terms *misinformation* and *disinformation* are often used interchangeably but the critical distinction between these confusable words is intent. Misinformation is false or misleading information that is spread, regardless of intent to deceive, while disinformation is meaningfully spreading misinformation.

"homophily" (McPherson et al., 2001). This is the inclination for individuals to configure social contacts with those who are similar and have similar interests to themselves, encapsulated by the general maxim "birds of a feather flock together." Strong homophily sentiments are manifest in polarized sets of social media users on opposite sides of the climate debate (Williams et al., 2015) and such actions are incited by social media platforms in the way new contacts and networks are both recommended, reinforced, and cemented. Taken with social conventions and the belief that individuals often trust information from people in their social network, this leads to "echo chambers" (Cinelli et al., 2021), where facts and dis/misinformation reverberate around a specific group. This can lead to further division and polarization where communities coalesce around deeply opposing opinions and views on an issue such as the climate crisis. Researchers found evidence that climate denial in political rhetoric has shifted and there is an uptick in dis/misinformation about climate change solutions, which is shaping public attitude about the nature of climate change and the efficacy of real answers and action (McCright et al., 2016). More troubling is how Big Tech is driving engagement with their platforms and, thus, continuing to automate the collection of vast amounts of discrete user information that is the basis of their "surveillance capitalism" economic strategy.[18] Put simply, these platforms make money from the length of user engagement time. Speaking to Johann (Hari, 2022) for his book *Stolen Focus*, YouTube algorithm designer and engineer Guillaume Chaslot explains that they have long figured out that videos that shock or offend hold the viewers' attention for longer. Therefore, their recommendation algorithm is designed not to give the viewer factual information but to offend, annoy and disturb. They leverage emotions such as anger and offense, which can lead to the elevation of contrarian and anti-science material over fact: and this operational approach and arrangement remains largely unchallenged and ably aided by the platform's digital algorithms. Findings from a recent study of Twitter, for instance, suggest a substantial impact of mechanized bots[19] in amplifying denialism messages about climate change (Marlow et al., 2020).

Discussion

This discussion section draws together some of the evidence of digitalization's "green" credentials to offer a more holistic narrative of where and how digital ICT is contributing to improved ecology and conservation, and summons closer attention to some of the areas of growing concern where such technology is contributing to increasing planetary harm. While it must be acknowledged that we are still in the early chapters of the Digital Age, the evidence from this review would suggest that in much of the literature on the contribution of digital ICTs to tackling the climate emergency and issues such as (over)consumption, words like "potential," "possibility," and "can" figure prominently.[20] This review also found that much of the potential at present is in the areas of more effective and efficient data capture, monitoring, and assessment of the harm currently underway, the communication of such harm and approaches for better resource management, attempts at behavioral change through information provision and allowing like-minded activists and groups to organize *via* online platforms. However, decisive action based on such data is far less established and apparent and there is a lack of urgency by many governments across the world to act on such data and evidence, as demonstrated in the finding from the 2021 Lancet Countdown (Romanello et al., 2021).[21] The provision of climate change information alone has ostensibly failed to bring about the necessary mitigation efforts appropriate to the degree and urgency of the climate emergency, suggesting that the "information deficit model" is inadequate (Knutti, 2019).[22] The scientific consensus on the causes and drivers of climate change is settled, not least our consumer-dependent lifestyles, so other barriers and pressures must be at play. There continues to be an absence of genuine political will and determination and a reluctance to act decisively (Leiserowitz, 2019), which is reinforced by the path dependency of fossil-fuel-based systems—-social, political, and economic—-ably assisted by Big Tech. Decisive action is frequently hampered by persuasive but misleading counterarguments amplified over online social

18 For an in-depth understanding of how surveillance capitalism works read Shoshana Zubboff's very insightful 2019 book of the same title.

19 A bot, which is shorthand for robot, is a computer program that functions as a proxy for an actual user or other programs. Its purpose is to simulate a human activity and such bots are generally used to automate certain tasks or activities on the internet. This effectively means they can run without any explicit instructions from individuals.

20 For example, a recent report for The Royal Society (2020) contained chapter and sub headings such as '[t]ransforming the future, [t]he potential of digital technology to support a low-carbon economy, [a] future digitally-enabled net zero economy and society. This all points to potential and possibilities but little evidences of digitalisations real impacts.

21 The Lancet report concluded that there has been 'little progress to protect its population from the simultaneously aggravated health impacts of climate change' and that 'as the world approaches COP26, the response to climate change, and commensurate investment, remains inadequate' (pp. 1653–1654).

22 The deficit model espouses a position that there are gaps between the public and the scientific community because of a deficiency or absence of specific information or knowledge. To rectify and close this gap, the deficit model is a broadcast communication strategy that permits information to flow from experts to the public in attempts to influence and change people's attitudes, beliefs, and or behaviours (Suldovsky, 2017).

media platforms. Indeed, using the tools powering the Digital Age, the fossil fuel industry is continuing its 40-year strategy to manufacture uncertainty and doubt about climate change: disparaging climate scientists, exploiting regulatory capture to its own ends, expunging the scientific record, using propaganda in and outside the classroom, and tricking the public into voting against renewable energy legislation (Bush, 2020). Furthermore, when it comes to consumption, the promise from digital ICT of dematerialization[23] has yet to be realized and, in some instances such as books and music, we are witnessing the beginning of a reversal of such a trend.[24]

Considering smart homes powered by digital ICTs, a Swedish study advocated that effects on energy consumption levels differ significantly across particular households, suggesting that households respond to energy feedback in a bespoke manner (Nilsson et al., 2018). Although smart meters in the home can lead to increased attentiveness to levels of energy consumption as well as improved home comfort, the study indicated that the potential for energy savings from such home systems is largely dependent on peoples' inclination and their ability to engage with the relevant information and features that are provided. The expectations that digitalizing home devices and gadgets alone will lead to a reduction in energy consumption have not yet been fully justified, it is argued, and instead of saving energy in some cases, digitalization has created supplementary energy consumption (Lange et al., 2020). This accumulative energy consumption may well persist, as energy-cutting effects often tend to induce new pathways that lead to energy-increasing outcomes. Moreover, while innovations like the IoT can potentially offer some energy-saving initiatives and consumption decrease, the question of the use of the collected data looms large. Many of these devices collect extraordinary amounts of personal and private data and, as Zuboff (2019, p. 153) argues: each new level of innovation builds on the previous one, and they are all united in one goal, the extraction of behavioral surplus at scale. The question of who collects this data, owns it, uses it, and for what purpose, is of extreme importance if the public is to have any level of confidence in such technologies. At present, the answers to these questions are clouded in secrecy and robustly guarded by the digital tech industry. The IoT will be accompanied, therefore, by a loss of privacy and the collection of enormous amounts of personal data, which opens the door to a much greater barrage of marketing and personally targeted advertising that will intensify unnecessary and needless patterns of consumption. Research on leveraging and capitalizing on the use of IoT data in advertising is already underway (e.g., Wei, 2022; Gai, 2022). But the evidence collected from the academic literature, from expert interviews and location visits suggests that, among other things, HEMS throws up a host of privacy and security issues, reliability concerns, forced lifestyle changes, the transparency and openness of the markets for such technology, the energy rebounds, and wasteful consumption, and the digital divide (Sovacool and Del Rio, 2020).

Using digital ICT personal devices, consumers are increasingly offered more information on the environmental impacts of the products they buy, as well as ways of reducing or changing their patterns of consumption to make them more sustainable. But research has shown that consumers often suffer from knowledge-action or intention-behavior gaps (Liobikiene et al., 2016). This means that, even when consumers intend to shop in more sustainable ways and are provided with the necessary information to do so, it does not inevitably translate into positive action. Indeed, further knowledge denotes a source of quandary, pressure, and paralysis leading to a 'self-inflicted sustainable consumption paradox' in individuals' efforts to lead more sustainable consumption lifestyles (Longo et al., 2019). The increase in public awareness of environmental issues, often brought about by digital ICTs, and the acceptance of the need for pro-environmental attitudes and actions, has not been followed by any substantive changes in behaviors for the vast majority of individuals, it is argued (Burgess et al., 2003). It is also reasonable to suggest that, for example, as individuals opt to work more from home, emissions related to the daily commute to a central work location and energy consumption in the workplace may well decline, but energy consumption associated with the home would correspondingly rise over time. The exact position is more nuanced. A UK study found that teleworkers travel farther each week than non-teleworkers, despite taking fewer trips (Caldarola and Sorrell, 2022). Findings from one recent study attempting to learn lessons from the pandemic reveal that there is not likely to be any reduction in emissions overall and the net result may be a small increase (Santos and Azhari, 2022). A recent Canadian study suggested that if workers continued to operate from home and maintained their existing energy consumption arrangements—-or even close to those levels—-this could lead to an escalation in energy consumption and amplified peak loads, and it would be challenging and financially costly for electricity suppliers to exactly match various supply and demand loads during the day (Villeneuve et al., 2021).

While there is potential for digital ICTs to have positive effects on consumption reduction and climate change, the growing demands from digitalization in terms of device and

23 The concept of dematerialisation is about the absolute or relative reduction in the quantity of materials needed to produce an item or product. It is a phenomenon that has emerged in tandem with digital ICT development and is most associated with the notion of the "paperless office."

24 Despite a significant increase in e-commence during the Covid-19 pandemic, the sales of books increased (Whiting, 2021) while Statista report the ongoing fall of e-reader sales for the period 2018–2025 (Haines, 2021). The sale of vinyl records have also indicated a remarkable resurgence in physical music sales (Gayle, 2021).

energy needs are more worrying. For digital ICT devices, there are complicated ethical problems that require deep reflection and consideration of who benefits from rare-earth element mining activities, who suffer its negative effects, and to what extent new mining ventures are even necessary. The environmental and social impacts in communities where such mining activity occurs may not be worth it and, paradoxically, in attempting to resolve some environmental problems through electric battery development companies are using approaches that only increase environmental damage and harm elsewhere. Electric Vehicles (EVs), in particular, are increasing demand for both Cobalt and Lithium, two of the world's rare-earth minerals. With ongoing debates over the energy consumption of data centres, there is evidence of some efficiencies over the recent past, largely because of the redundancy and replacement of less efficient facilitates. Now that many of the traditional energy-intensive smaller data centres have been phased out and replaced by hyperscale data centres, it is likely that we are at the early stages of the rebound effect. Even considering data centre efficiencies, electricity demand remains flat at present, but it is questionable what this demand will look like in a decade or so. To maintain and keep data centres running efficiently and effectively, a significant amount of power and energy is needed, in particular for cooling. When data is processed, heat is generated, and additional energy in the form of cooling is needed to prevent servers from overheating. This heat is often viewed and treated as waste and simply released into the atmosphere, so much more attention is needed by the industry on how such energy can be saved, redirected, and reused. One solution in terms of energy use is to locate such data centres in cooler regions and push the colder outside air into these facilities. There are also some possibilities to reuse such energy to heat homes, swimming pools, and greenhouses, or to feed this energy into regional grids.

From a socio-economical perspective, the digital tech sector is dominated by just a few extremely large online platform corporations (Bissinger, 2017) that, through their promotion of an on-demand consumer-dependent lifestyle and personalized advertising, are accelerating a consumerist culture of online shopping, increased packaging waste, unsustainable product air miles and parcel deliveries that are further fuelling the climate crisis (Chua, 2021). Our private lives are increasingly being appropriated and monetized by these digitized platforms and individuals are being manipulated in very sophisticated ways to operate against our better judgment to consume and accumulate more *stuff*, all of which harms the planet. In many discernible and complex ways, digitalization is simply automating the worst of consumer culture to accelerate the climate crisis. An ITV News undercover investigation, for example, revealed that thousands of unsold electronics, including laptops, smart TVs, and all their respective packaging, were being destroyed needlessly by Amazon (Pallot, 2021). These were all products that were unsold after a specific period or had been returned by customers, and according to Amazon's business model, it is often cheaper to destroy these goods and items than store them. Overall, the net contribution of digital ICTs to reducing negative environmental impacts has yet to be fully determined, sector by sector, and much of the debate and discussions are largely made up of platitudes and aspirations. Digital ICTs contribution to (over)consumption is more obvious as it digitizes, automates, and accelerates production and consumption, all of which challenge the constraint that is needed to tackle climate change.

Conclusions

This review of the ecological impacts of digitalization is a call for closer engagement with the environmental realities of the Digital Age, and how Big Tech has been largely allowed to determine its direction and future without much oversight or antagonism (Radu, 2020). Left unfettered, the industry will continue to pursue a consumer-dependent trajectory that is damaging to the planet. As the eminent educator, author, and environmental activist Chet Bowers (2016, p. xiii) put it: "while the digital technologies appear to be new, they are based on the same deep cultural assumptions that underlie the industrial/consumer-dependent culture that is overshooting the sustaining capacity of the earth's natural systems". But alternative pathways and futures are available to pursue. (Ferreboeuf et al., 2019) calls for a sober digital transition to a "lean" approach to ICT that will help limit emissions and refocus the industry to become truly "Green ICT."[25] Based on their past practices and conduct, the digital tech industry alone cannot be trusted to act appropriately without some oversight. The implications of this review may well be that cutting back on our insatiable appetite for devices, data, and services—-a personal digital sobriety approach—-is one way to prevent energy use from going into overdrive over the coming years. But in tandem with reducing our electronic device and energy consumption, governments and international organizations must be much more proactive and rigors in curtailing the excesses of Big Tech and digitalization. These corporations have every right to be for-profit-driven, but not at any cost. Their record in living up to their social and environmental responsibilities leaves a lot to be desired, so it is time that they are forced to disclose

25 The Shift Project calls for:
1. Companies and governments to adopt digital sobriety as a principle of action
2. Accelerate the awareness of the digital environmental impacts
3. Include environmental impacts as decision-making criteria
4. Enable organisations to manage their digital transition
5. Undertake carbon audits for digital projects
6. Improve the consideration of digital systemic aspects in key sectors
7. Implement those actions to the European level.

and own up to their material environmental failings and are held to account when they are deceitful or act against the public interest.

Some limitations of this study must be acknowledged. As a desktop review performed by a solo author, every attempt was made to capture and collect the most up-to-date literature and data, but this does have its limits in terms of time and scope, and some level of subjectivity is inevitable. In addition, it was not possible to cover every aspect of digitalization, but an attempt was made to cover the most significant elements and features, in particular concerning sustainability and the environment. The review adds vigor and impetus to discussions and debates around the sustainability of digitalization and challenges some of the assumptions, misapprehensions, and public utterances from the industry. Such a review challenges the industry's "do the right thing"[26] rhetoric and infers growing environmental concerns and draws more attention to the fact that greater civic and social responsibility is required from the industry: in the absence of which, regulation is needed to protect society and the planet. A sustainable Digital Age makes proper use of digital ICTs and knowledge for fostering and promoting a good life for all, current and future generations. This is achieved through "strengthening biological diversity, technological usability, economic wealth for all, political participation of all, and cultural wisdom, and achieving a sustainable digital future costs: it demands a conscious reduction of profits by not investing in the future of capital, but the future of humans, society, and nature" (Fuchs, 2008, p. 308).

26 Google's unofficial motto had long been 'don't be evil' but when they were reorganised under their new parent company Alphabet in 2015 an adjusted version of the motto was introduced: "do the right thing."

Author contributions

MH was solely responsible for the conceptualization, writing, and editing of this manuscript.

Acknowledgments

The author wishes to acknowledge the assistance provided by the Social Science Research Centre (SSRC) at the University of Galway in allowing the use of the centre's facilities in the writing and editing of this manuscript.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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