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THE ENVIRONMENTAL DARK SIDE OF DIGITALISATION: an urban perspective

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As primary hubs of consumption in an urban world, cities generate an ever-growing demand for energy-intensive digital services. If city governments are to stay true to their ambitious climate mitigation goals, they must play a pivotal role in addressing digitalisation's environmental impacts and carbon emissions.

City governments can already act by promoting the circularity of the massive amounts of heat generated by the rising number of data centres in cities and the "urban mining" of the valuable materials contained in the expanding volume of e-waste.

According to the Paris Agreement and the Intergovernmental Panel on Climate Change (IPCC), the safety threshold to avoid the worst impacts of climate change is to limit global warming to 1.5°C above pre-industrial levels by reaching carbon neutrality before 2050. Yet the implementation of the current climate pledges by national governments is projected to lead the planet to an increase of 2.5°C by the end of this century. Against this backdrop, the need for a comprehensive ecological transition of our society is gaining traction across public discourse.

Since fossil fuels account for over 75% of anthropogenic greenhouse gas (GHG) emissions, the call for decarbonisation is the obligatory passage point for a green transition. The decarbonisation of energy, transport, buildings, industry, and land uses is increasingly associated with the expanding opportunities provided by digital innovation. From facilitating energy efficiency and the uptake of renewable energies to fuelling the rise of lab-grown meat, the green and digital transitions are mutually reinforcing transformative processes.

The increasing perception of the green and digital transitions as two sides of the same coin – also defined as the *twin transitions* – has even prompted the European Commission (EC) to adopt this theme as the focus of its 2022 Strategic Foresight Report "Twinning the green and digital transitions in the new geopolitical context". Against the backdrop of the implications of Russia's war against Ukraine, the EC identifies a spectrum of areas for action ranging from transitioning to clean energy to boosting smart farming in which present and future critical technologies will play an instrumental role. As such, its strategic reflection banks on the transformative capacity of digital technologies to contribute to achieving climate neutrality and reducing environmental degradation. The reliance on digitalisation to fight climate change by a global heavyweight institution such as the European Union (EU) is testament to a broader societal viewpoint according to which high-tech actors are fundamental partners in the ecological transition, in stark contrast with the fossil fuel industry and its obstructive role in the process.

However, viewing digitalisation as a fundamental ally on the path to climate neutrality risks missing the crucial point that digital services and infrastructure produce a significant carbon footprint and environmental damages of their own. While the environmental consequences of digitalisation are gaining some prominence, awareness of the scale of this phenomenon and its projected expansion over the coming decades has not received the scrutiny it warrants across policymaking institutions. The present article contributes to this call for attention, and it does so from an underexplored angle: the environmental impact of digitalisation from an urban perspective.

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The rationale is that in an increasingly urbanised world, cities generate an ever-growing demand for energy-intensive digital services and infrastructure. City governments have the responsibility to wield their political legitimacy, legal competences, and on-the-ground experience to tackle this growing phenomenon. As policy actors with a track record of ambitious mitigation goals, local administrations must play a pivotal role in addressing the environmental impacts and carbon emissions of digitalisation. Yet in the digital world questions of scale are paramount, defining the limits and opportunities that city governments face when tackling this snowballing phenomenon.

As an initial contribution to a (still) relatively marginal issue, the article seeks to bridge the general material underpinnings of digitalisation and the policy areas where city governments can take action. The first three sections below focus on the general level, illustrating the synergies and contradictions of the green and digital transitions, the energy-intensive nature of digitalisation and its exponential technologies, while noting that the impact of the rising digital world goes beyond its expanding carbon footprint to encompass broader environmental considerations. The last two sections ground this analysis to the level of urban policymaking. They note that city governments need broader alliances to tackle the opacity of data on the wide digital supply chains circumventing their territorial jurisdictions adding that, meanwhile, they can harness the circularity of heat and e-waste associated with the rising number of data centres and e-waste generation in cities.

Digitalisation and dematerialisation

One positive piece of news in the context of the climate emergency is that from the 2010s onwards (with the exception of the rebound effect from the pandemic in 2021) growth in terms of global gross domestic product (GDP) and the rise in carbon emissions have decoupled. While the former has grown considerably, the latter has undergone a smaller increase. Since lower emissions have always been linked to economic slowdowns, this historical turnabout shores up the view whereby technology acts as the main catalyst in the fight against climate change.

Once political will and economic investments are in place, the argument goes, as a society we already have the technological resources to adequately address the climate emergency over the next decades. From this perspective, digital technology plays a fundamental role on its own, having the potential to contribute to cutting global carbon emissions by up to 15%. As with the chips currently powering our computers, exponential technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and 5G may soon pave the way for sustainability in multiples sectors of the economy thanks to their falling prices and exponential growth.

Unfortunately, however, digital technologies will not play the groundbreaking role we hope, at least not on their current unsustainable trajectory. While increasing energy efficiency has been key to the process of decoupling to date, the absorption of renewable clean energy and its massive expansion to the detriment of fossil fuels should be the game-changers of the green transition in the coming years. Yet this transformative mission is jeopardised by growing energy demands, which are also driven by the expanding use of energy-intensive digital services and infrastructure.

> Digitalisation is not dematerialised as pompously depicted. Beneath the ongoing digital transition lie billions of electronic devices, data centres and servers, and the millions of kilometres of cables supporting connectivity networks globally.

Beneath the ongoing digital transition lie billions of electronic devices at our fingertips – from widely popular smartphones and computer screens to relatively more recent watches and Bluetooth speakers –, data centres and servers, and the millions of kilometres of cables supporting connectivity networks globally. Digitalisation is not as dematerialised as pompously depicted. The bleak corollary is that the digital carbon footprint is increasing by 8% on a yearly basis (Itten *et al.*, 2020). Not only do the components necessary to keep digital services and infrastructure running consume huge amounts of energy, their use is expected to rocket because of the very nature of these exponential technologies. Key figures can help to illustrate the scale of this phenomenon.

Exponential technologies and their carbon footprint

Since 2010, global traffic on the internet has grown 20-fold. This means that there are 4.95 billion internet users across the world, with an increase in internet users from 2021 to 2022 of 192 million. It is an even more remarkable figure if we consider that in that same period the world's population increased by 80 million. Accounting for 7% of total electricity use globally, if the internet were ranked as a country it would stand as the sixth-largest consumer in the world (Schwarzer & Peduzzi, 2021). According to estimates, in 2019 the digital world produced almost 4% of global carbon emissions, a figure that already eclipses the total emissions of civil air traffic worldwide.

As mentioned earlier, in addition to this gloomy scenario we need to factor in the ascending growth and consequent carbon-based energy consumption of exponential technologies. Despite significant improvements in terms of energy efficiency, global energy demand is rising partly as a result of the latest innovations. Paradoxically, these technological disruptions are also welcomed since they are expected to play a catalytic role in the green transition. Hence the complex relationship between the twin transitions.

AI and machine learning, for instance, can enhance our monitoring and predictive capacities, leading to less resource-intensive processes in such disparate domains as real-time data analysis in transport systems, evidence-based decisions for climate adaptation, or agricultural production. Yet training a single AI model, for instance for natural language processing (e.g. ChatGPT), generates nearly as much carbon as five average American cars throughout their lifetime emissions, including their manufacturing process. As tech giants such as Google and Microsoft race to provide their millions of users with generative AI-powered tools, the total energy use and carbon footprint could increase significantly, all the more so if we consider that AI models need to be retrained on a regular basis to incorporate new data.

> The dark side of the rising digital world goes beyond the expanding carbon footprint to encompass broader environmental considerations. Three are worth mentioning here: water, minerals and waste.

Likewise, blockchain is a distributed ledger technology that records transactions simultaneously across multiple places in a decentralised way, improving the interaction, tracing, and self-organisation of data across actors and components. As such, it is another field where the green and digital transitions intersect. For instance, it can be instrumental in facilitating self-organised grids that improve the security and transparency of energy systems, boosting the circular economy by tracking the life cycle of products and services, and powering reward-based systems that incentivise citizens to shift from fossil fuel-based transport to carbon-neutral mobility. Yet the underlying computing calculations needed constantly to verify transactions can make blockchain a highly energy-consuming technology. For instance, the electricity consumption of Bitcoin, a blockchain-powered cryptocurrency, surpasses the total consumption of countries such as Argentina, the Netherlands, and United Arab Emirates.

Beyond carbon: water, minerals and waste

Yet the dark side of the rising digital world goes beyond the expanding carbon footprint to encompass broader environmental considerations.[1] Three are worth mentioning here: water, minerals and waste.

Data centres, which are a key component of the physical infrastructure underpinning the internet, are highly resource-dependent. Accounting for 1.5% of global electricity use, data centres have also improved their energy efficiency recently, in line with the broader patterns sketched above. Yet much of this electricity saving has been achieved by replacing air conditioning with water cooling. In the US alone, 20% of data centres already rely on watersheds under stress. Looking into the future, it is expected that globally in 2030 there will be a water gap of 56% between demand and supply. In the face of the rising global demand for this common good by an expanding population, the direct and indirect water footprint of data centres will be increasingly problematic in the context of climate change, ultimately exacerbating water scarcity, competition for resources, and food insecurity.

In other instances, however, energy efficiency in technological devices is achieved by deploying refined components that still have significant impacts throughout the life cycles of products. This is the case of raw minerals whose extraction and manufacturing processes are as polluting as they are difficult to decarbonise. Furthermore, the location of mineral deposits and the associated dynamics of extraction lend additional complexity to the domain of material resources necessary for digitalisation. For instance, over 70% of the world's cobalt, a key raw material for the batteries of mobiles and electric vehicles, is produced in Democratic Republic of the Congo (DRC) and has been repeatedly associated with episodes of environmental damage, human rights violations and armed conflict. On a different note, the fact that China supplies 80% of the world's rare earth elements, which are fundamental in hi-tech products as diverse as LCD/LDE screens, wind turbines, and

1. While brought about by the same phenomenon, the negative social consequences of digitalisation are paramount and complex. As such, they deserve a separate discussion beyond the scope of this article.

military weapons, has strategic implications within the current geopolitical tensions.

A life-cycle perspective on the products of our everyday life leads us to a third dimension of the environmental impacts of digitalisation. A sharp increase in the production of electric and electronic equipment, their short life cycles, and an inadequate culture of repair led to the generation of an unprecedented 53.6m tonnes of e-waste in 2019. The world is projected to almost double its global generation of e-waste between 2014 and 2030 (Forti *et al.*, 2020). The generally short use phase of many digital devices masks a longer life cycle with broader impacts – through the consequences of raw materials extraction and manufacturing processes, first, and the inadequate collection of e-waste, later. In addition to environmental impacts, e-waste further implies public health consequences as it comprises toxic metals such as mercury and cadmium.

Questions of scale are of paramount importance since the wide supply chains of the digital world circumvent the territorial jurisdictions of city governments.

Highly consuming cities and opaque digital services

As the breadth and depth of the environmental impact of digitalisation becomes clear, we can now unravel its less explored relationship with an increasingly urbanised world. As will be clear by the end of the next section, questions of scale are of paramount importance since the wide supply chains of the digital world circumvent the territorial jurisdictions of city governments.

With more than 56% of the world's population currently living in urban areas, cities currently account for 67-72% of global GHG emissions and are responsible for 75% of the world's energy consumption. At the same time, they produce more than 80% of global GDP. The economic and demographic centrality of cities in the "urban age" have led city governments to seek to enhance their role in global governance, aiming to contribute positively to policy areas where cities had long been perceived in a negative light in terms of environmental sustainability (Martinez, 2022). In the current context of climate emergency, this drive has led city governments to be more ambitious than their national counterparts in terms of GHG emission reduction goals overall. This the case of over 1,100 cities around the world that have committed to achieving net zero carbon emissions by 2050.

Cities spatially concentrate the key resources necessary to manage the flows that sustain globalisation. As such, they are the cradles of wealth that act as powerhouses of today's increasing consumption of energy-intensive digital services and products. In line with their assertive role in climate mitigation, cities could aim to analyse and tackle the digital underpinnings of the economy and energy systems that need to be decarbonised within their jurisdictions. This is because of the fundamental connection between cities and consumption in our current global economy. Not only do cities cluster the activities that are propelled by carbon-based energy and generate GHG emissions, but they also drive the consumption patterns that ultimately define those emissions (Castán Broto, 2021).

Unfortunately, decarbonising the growing digital infrastructure of our highly consuming cities is hampered in the first place by the basic hurdle of obtaining accurate data at local level. Localising the calculation of the digital world's carbon footprint is complex for two reasons. Firstly, most of the relevant environmental impacts of digital services are generated beyond city governments' operations and public organisations more widely. Secondly and even more importantly, the measurement of the whole life cycle is challenging per se. By definition, digital services – and this is where the fallacy of dematerialisation kicks in – are produced in a geographically decentralised way, with little transparency and accuracy about the location and relevant electricity use, carbon-based energy consumption, and environmental impacts of each of the components across the digital sector's wide, transnational supply chains.

Therefore, city governments cannot properly assess – not to mention reduce – the carbon footprint of the energy-intensive digital services and products consumed within their urban jurisdictions. Nonetheless, city governments could scale up their proactive role in mitigation efforts, much in line with the growing relevance of transnational city networks through which local governments amplify their climate action, span different scales, and pool resources. Multi-level and multi-actor alliances devoted to monitoring and addressing the digital carbon footprint in and between cities could benefit from the on-the-ground experience, legal competences, and political legitimacy of city governments. Yet for this to be feasible, the diverse private sector actors involved across the wide supply chains of the digital sector must actively collaborate by providing transparent and accurate data on their operations through government-established reporting mechanisms. Likewise, because of the transnational dimension of the distributed networks through which digital services are produced, cross-border mechanisms for reporting would be of strategic relevance. In this regard, the EU's degree of integration as a supranational governance structure would make it the ideal testbed to analyse and tackle the digital carbon footprint of cities at the regional level.

Local circularity of heat and e-waste

Nonetheless, there are two concrete policy areas where city governments, regardless of broader multi-level and multi-actor alliances, can already take action to decrease the environmental impacts of an increasingly digital (urban) world. They both relate to the opportunities offered by the circularity of material flows in our cities.

First, data centres, which are at the core of the material underpinnings of digitalisation, are increasingly located in cities. The rising relevance of technological applications such as cloud gaming, virtual reality, or online gambling, which seek to replicate the real-time speed of our real world, rely necessarily on increasingly speedy connectivity. The decision by technological corporations to rely on urban data centres within their expanding distributed networks speaks to the growing need for physical proximity to the zones where digital consumers are most (densely) concentrated – cities. The location of data centres in urban areas offers the environmental opportunity[2] to reutilise the massive amount of heat generated in them to contribute to cities' transition towards green energy mixes. The Stockholm Data Parks initiative, for instance, is an example of productive synergy between green and digital agendas by which the government of Sweden's capital city and its partners aim to attract data centres and deploy heat recovery systems, ultimately contributing to the goal of becoming fossil-fuel free by 2040.

Second, as shown with regards to the localisation of the digital carbon footprint, the environmental impacts of digitalisation in a city should not be confined to the production-based effects generated within its territorial jurisdiction but rather encompass the consumption-based effects generated by any given demand within its territorial jurisdiction. As such, city governments can and should play a pivotal role in the broader chain of environmental impacts and carbon emissions associated with digital products and services that are overwhelmingly consumed in urban areas.

2. The impact of this rapidly growing phenomenon encompasses further aspects beyond the scope of this article, such as spatial integration and governance innovation.

Also thanks to the possibilities provided by digitalisation sketched earlier, cities are uniquely placed to harness the physical concentration of demand and supply they host and boost a circular economy where materials are maintained as long as possible, rather than converted into waste. As with construction materials or plastics, e-waste can also feed into the circular development of a city. With only 17% properly collected and recycled (Forti *et al.*, 2020), the e-waste in dumpsites contains materials that are both valuable and toxic. This comprises both a key opportunity and a necessity, as specific legislation and jobs are needed in what has been defined as urban mining. The extraction of resources from e-waste is cheaper and less energy-intensive than extracting virgin materials for the production of technological devices and putting further pressure on the planet's natural resources.

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The opportunities provided by the local circularity of material flows underpinning digitalisation such as heat and e-waste may initially seem an avenue for policy action that is limited to cities in the Global North. After all, the growing presence of data centres and the possibility to deploy heat recovery systems is particularly relevant for cities that are increasingly turning to knowledge-intensive development and technological innovation. In Singapore, for instance, data centres account for 7% of the city-state's total electricity use. Likewise, this scenario is attuned with cities that are experiencing clear patterns of tertiarisation of their economies, as in Barcelona, where services and commerce account for 35% of final energy consumption, more than any other sector.

Yet the fact that governments in such disparate contexts as Iran and New York State have recently decided to curb crypto mining – to tackle power shortages and fossil fuel-powered energy consumption, respectively – is an indicator that the scope for environmental action on digitalisation goes beyond cities in the Global North. This is precisely because of the pervasive, decentralised and transnational nature of the chain of production and consumption of digital products and services. By the same token, there is increasing acknowledgment of the relevance of the circularity of e-waste in cities in the Global South, as demonstrated, for instance, by the experience in Accra through which workers learnt how to disassemble components safely and cleanly from the largest e-waste disposal site in Ghana.

Conclusion

While there is a general awareness of the fossil fuel industry as an impediment to the ecological transition, the environmental impact of high-tech actors is a relatively new topic in public discourse. The green and digital agendas are twin transitions in that they offer promising synergies that contribute to our collective response to the climate emergency. Yet they warrant closer scrutiny as the expansion of the digital world and its exponential technologies is simultaneously propelling carbon-based energy consumption.

There is even less acknowledgement across policy discussions that, in an increasingly urbanised world, cities host most of the present and future rising demand for energy-intensive digital services and infrastructure. Their attractiveness as policy actors stems from being the primary hubs of consumption of the current global economy, as well as from their track record in climate mitigation goals, surpassing the levels of ambition demonstrated by national governments.

The possibilities of city governments are simultaneously limited and amplified by questions of scale. On the one hand, the capacity of a city to decarbonise the growing digital infrastructure within its territorial jurisdiction is hampered primarily by the opacity of data. With the private sector playing a fundamental role in the distributed and wide supply chains through which digital services are produced, government-established reporting mechanisms are needed to operationalise transnational multi-actor and multi-level alliances devoted to monitoring and addressing the digital carbon footprint in and between cities. On the other, the rising number of data centres generating massive amounts of heat in urban areas and the opportunity and need to both regulate and harness the materials contained in the unprecedented generation of e-waste provide city governments with the opportunity to take immediate action. In the coming years, the circularity of material flows underpinning digitalisation such as heat and e-waste will be increasingly relevant for cities across the Global North and South. The environmental impacts of an increasingly digital (urban) world will only increase and city governments must better prepare for that.

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