Digitization of Ecology and Ecologization of Media

Going Beyond ICT Environmental Impact

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Abstract: Digital media and the environment pose some of the most urgent social issues of our time. Nonetheless, the relationship between them is often neglected and merely addressed in terms of impact. This scenario frames these topics in a chiastic relation, thus enquiring two processes: the digitization of ecology (both as a science and as a socio-political practice) and the ecologization of digital media (both in the sense of their greening and of their evolution into mediascapes). On one hand, by drawing on the Ecology of Information Infrastructures and the Actor-Network Theory approaches, environmental issues will be considered as a matter of digital communication and participation. On the other hand, the troubles of digital societies will be addressed from an environmental perspective, adopting the SCOT approach, and embracing the Media Ecology tradition to outline and call for digital sustainability strategies.

Keywords: digital media, ecology, environmental informatics, dematerialization, green IT, mediascapes

Submitted: June 19, 2020 – **Accepted:** February 26, 2021

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1. Looking Beyond Impact

For at least fifteen years, issues concerning either the environment or digital technologies have been prevailing in the public debate. On a daily basis, news, reports, political statements, and many other kinds of information instruct us about risks and opportunities deriving from our ecological or digital behaviours. A small example displaying the extent of this process is that among the 23 words of the year chosen by the Oxford

English Dictionary between 2004 and 2019, five of them related to digital media and four to the environment (Oxford English Dictionary 2020). Despite the wide attention directed to ecology and digitization as single issues, the public as well as mainstream media seem much less interested in their possible relationships. On top of that, when a relation is built, most of the times it addresses information and communication technologies' (ICTs) environmental impact in quantitative terms.[1] The aim of the following pages is precisely to overcome such an approach through Science and Technology Studies (STS), providing an alternative perspective on it and, most importantly, identifying other possible connections between digital media and the environment.

Thus, two processes will be inquired: the digitization of ecology (both as a science and as a socio-political practice) and the ecologization of digital media (both in the sense of their greening and of their evolution in terms of informational environments). At a first glance, this reversal might appear as a mere exercise in style but crossing words in a chiastic relation might provide useful insights: this paper invites to consider environmental issues as a matter of digital communication and, conversely, to interpret digital society's troubles from an ecological point of view. These tasks require a multidisciplinary gaze that, drawing on different theoretical perspectives, spans from sociology of science to environmental sociology and media studies.

In particular, digitization of ecology addresses how digital technologies affect both the production of environmental knowledge and the participation into ecological issues. As such, digital ecology first implies a sociology of science tailored on the community of environmental scientists and on their research work. Here the ecology of information infrastructures (henceforth: EII), and particularly Susan Leigh Star's work, represents a sound perspective to adopt. By inquiring the production of scientific knowledge through a relational lens that highlights the tension between universalistic vocations and situated practices, EII allows to see digital technologies as a crucial but unstable information infrastructure for environmental scientists, whose analysis can shed light on the current environmental debate. Secondly, digital ecology also pertains to environmental sociology and media studies, as it calls into question issues con-

[1] Emerging as a field of research in the 1990s, ICTs' environmental assessment represents the earliest and most common approach to the relationship between digital technologies and the environment. Providing a balance of direct effects in terms of energy use, resources consumption and waste production, ICTs' ecological impact is a technical and multidisciplinary subject, traditionally embraced by "hard" sciences such as industrial ecology, energy engineering, and informatics. Social sciences have sometimes contributed to this field by adopting a quantitative approach to evaluate ICTs' indirect effects. Inquiries into other kinds of relation between ICTs and the environment have been only marginal (Mol 2008, 10-16).

cerning environmental information and participation. Recurring to insights from Bruno Latour's and Noortje Marres' work in the frame of Actor-Network Theory (ANT), digital media can be seen as a broad array of hybrid and socio-technical networks, in which human and non-human actants interact according to different logics with different implications. Together, EII and ANT can help to understand the role of digital technologies in producing environmental knowledge as well as in facing the environmental crisis.

The ecologization of digital media pertains to two further and distinct processes inherent to media studies. First, it refers to the influence of environmental concerns towards the evolution of digital devices and infrastructures, whose greening, i.e., the mitigation of their own environmental impact, has been occurring through several socio-technical innovations. Following the tradition of Social Construction of Technology (SCOT), this process emerges as a battleground in which different social groups struggle to affirm their technological framework through different practices and values. Finally, to speak of ecological digital media also means looking at their evolution in terms of mediascapes, i.e., informational environments installed into the physical space. In this sense, the Media Ecology (henceforth: ME) tradition represents a crucial tool for understanding this process, the digital issues it raises and some possible solutions. Addressing green/ecological media through SCOT and ME will allow to understand whether and how environmental concerns affect the development and use of digital ICTs.

Digital ecology and ecological media thus represent two wide and challenging subjects, which often overlap rising possible misunderstandings. For this reason, the next section specifies the meaning assigned to key terms like "ecology" and "digital media". The following four paragraphs address the issues of digital ecology and ecological media by reflecting on selected literature revolving around EII, ANT, SCOT and ME, and by putting forward some thought-provoking arguments. Finally, the conclusive section summarizes the key points of this scenario.

2. Ecologies and Digital Media

When talking of ecology, we will refer both to the namesake scientific discipline and to those socio-political practices often labelled as environmentalism. While being aware of the many differences occurring between them, it is important to remind that a radical distinction is not adequate, given how complex, heterogeneous, and intertwined these two domains are. Environmentalism acts as an umbrella term for many different things such as, among others, nature conservation, the rise of green political parties, environmental information, communication, education, and activism (Nebbia 1999). Furthermore, all these activities derive from scientific ecology, a multidisciplinary field whose epistemological status, classifica-

tion, and affiliation are controversial, having often changed over time accordingly to the dominant paradigms and to the scale of observed events (Bellamy Foster and Clark 2008). Spanning from the atom to the ecosphere (Odrum and Barrett 1971, 4-7), ecology appeals to physics, chemistry, biology, geology, climatology, and many other natural sciences. In addition, it has several concrete applications in the fields of engineering and industrial production. Being a domain in which modern separations show up with all their artificiality (Latour 2012), we will use the term "ecology" in an inclusive way, referring to diverse environmental sciences and to the several social practices they inform.

As a hybrid science whose main subject are relations, ecology has also inspired many approaches to social reality, including EII and ME. Neil Postman (1970, 161) defined the latter as "the study of media as environments", urging to deepen into "the interaction between people and their communications technology" to understand how these "affect human perception, understanding, feeling and value". Thanks to the "powerful metaphors of media as ecologies and environments" and to "its focus on the materiality of technological artefacts" (Trerè 2019, 44) ME is a valuable tool to inquire the ecologization of digital media as mediascapes. On its turn, EII goes beyond media to bring human agency into play and to "include the network of relationships, values, and motivations involved in technology use" (Trerè 2019, 41). In their seminal work, Star and Ruhleder (1996, 117) clarify that "the term ecology (…) refers to the delicate balance of language and practice across communities and parts of organizations; it draws attention to that balance (or lack of it). It is not meant to imply either a biological approach or a closed, functional systemic one". To avoid possible misunderstandings, it is important to remark that the word "ecology", both in ME and in EII, is a matter of method, rather than content.

While referring to ecology in a broad and metaphorical way, our analysis needs to narrow the category of digital media both in meaning and in time. On a conceptual level, we exclude digital codes, as these comprise all communication systems made of discrete units, including, for instance, the human language. Rather, we identify digital media with those devices and infrastructures that allow information processing through electricity (Granata 2009, 107-108). Still, we further need to narrow the temporal field. Starting from electricity's informatization, in fact, would imply to consider technologies such as the telegraph, the radio, the television, and electronic calculators, whose relationships with ecology are out of our scope. Rather, we trace a meaningful turning point for digital media history back to 1969, when packet switching was successfully tested to send a message across the ARPANET, the first computer network. That experiment marked a symbolic watershed, starting a qualitative change hardly spottable at any other time in the evolution of digital devices, which could now exchange resources between them and increase their computational power through the network. Somehow, they started talking to each other,

and not just to humans. When discussing digital media, the paper will thus refer to digital connectivity's devices and infrastructures, calling into question mainframe and personal computers, laptops, smartphones, as well as early computer networks, software, the Internet, the World Wide Web, and mobile apps.

3. Digitizing Ecology

3.1 Environmental informatics as unsteady information infrastructure

It is common belief that scientific knowledge benefits from digital technologies, as these allow accurate measurements, faster field detections, complex data processing and a better communication within the scientific community. Environmental scientists embraced this view from the beginning, extensively drawing upon computer applications for environmental monitoring and control. The application of information systems to ecology dates back at least to 1975, when the first text in the field was published under the title *Computer Techniques in Environmental Science* (Ouellette et al. 1975). Today, the marriage between ecology and digital media is solid as ever, being structured in a specific discipline called Environmental Informatics (Hilty 2014). Nevertheless, from the ecological perspective of information infrastructure, the relationship between science, including ecology, and technology seems much less taken for granted and much more problematic. In particular, if we consider that "an infrastructure occurs when the tension between local and global is resolved" (Star and Ruhleder 1996, 114), one can argue that environmental informatics have never been a stable information infrastructure, given that such a tension continues to persist.

This is particularly evident in climate studies where, despite an ever-increasing amount of information has been digitally processed, consensus still lacks, making the climate change debate a political issue of global relevance and an ongoing scientific controversy. As a science enquiring a global phenomenon, climatology's development is strictly connected to digital networks. Not by chance, it has been among the first fields in ecology to exploit computer networking from the very beginning. Global climate dynamics simulation and modelling, and air pollution risks are the only environmental projects listed in the *ARPAnet resources handbook*, a directory of research institutions connected through the ARPAnet (Feinler 1978, 297; 312; 565). The relationship between climatology and informatics is thoroughly investigated in Paul Edwards' book *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming* (2010). Here the author retraces the whole story of global climate knowledge, showing that digital media helped in *making global data*

(Edwards 2010, 187-227) but at the same time posed difficulties in *making data global* (Edwards 2010, 251-285). This means that while digital technologies lessened *data friction* (i.e., the process of gathering data collected in different times and locations), they also enhanced *metadata friction* (i.e., the inconsistency of those data's original, local context). Such enhancement is not depending on digital technology in itself; it is rather the consequence of how scientists conduct their work through it. Researchers always omit some metadata, for either technical limits or negligence, causing metadata friction to other scholars. Retaining the context, moreover, is a sensitive issue concerning every discipline, including other environmental sciences (see, for zoology: Star and Griesemer 1989; for biodiversity: Bowker 2000; for taxonomy and genetics: Waterton et al. 2013). Nonetheless, by connecting very different contexts across the world, digital media have highlighted the inconsistency of situated scientific practices. At the same time, however, the scientific community envisioned a possible solution in the same digital technologies.

To reduce heterogeneity and to adjust metadata for making them global, as Edwards (2010, 188) puts forth, "scientists developed suites of intermediate computer models that converted heterogeneous, irregularly spaced instrument readings into complete, consistent, gridded global data sets". Computer-aided data models "are really a vast family of mathematical techniques, algorithms, and empirically derived adjustments to instrument readings" (Edwards 2010, xv). Recalling Bowker and Star (1999), Edwards names these continuous efforts to recover original metadata and to build comprehensive datasets as infrastructural inversion. This is "a long and painful process [that] began in 1970s [and through which] climate scientists turned the climate record upside down, reexamining every element of the observing system's history, often down to the level of individual measurements" (Edwards 2010, xvi). Nonetheless, infrastructural inversion through data models poses the same problem again, but on another level. Different scientists and laboratories always create different data models, starting some kind of "data wars: rather than one definitive global dataset, multiple, competing data sets will emerge" (Edwards 2010, 435; see also: 287-322). In short, digital technologies allow gathering larger volume of data, but they cannot guarantee the consistency of their original contexts: on the contrary, they highlight incoherence. Moreover, when used to recover the context or to correct previous detections, digital technologies fuel further debates because they allow multiple ways to do that.

This is exactly where the widest and most urgent environmental issue of our time is stuck. Climate change supporters and deniers are such according to the (meta)data they collect and elaborate, a process that increasingly happens through digital media. Of course, economic and political interests play a major role in this debate, benefiting from the lack of consensus. Nonetheless, the crucial point is that the two factions support their thesis through some kind of digital data: somehow, climate change is

a digital issue. The same applies for other ecological controversies, as those connected to pollution, contamination and toxicity issues in which risk thresholds are heavily debated.

Environmental informatics is thus an unstable infrastructure, which has not yet stabilized, and which is still in inversion. Environmental scientist should take it less for granted, focusing much more on its situated use. Following Bowker and Edwards' suggestions, they should increasingly cooperate with social scientists and with each other by building stronger international institutions and information infrastructures. For climatology, the institution of the Intergovernmental Panel on Climate Change (IPCC) in 1988 is a first step in this direction but, given the ongoing and multiple controversies, there is still a long way to go.

3.2 Non-human agency between material participation and dematerialization

Besides environmental sciences, digital media play an increasingly relevant role into environmentalism, as they evolved from mere informational tools to complex participatory systems. While media studies allow to identify the most important stages of this process, to integrate environmental sociology with the ANT attention towards non-human agents sheds light on its implication, both in terms of participation and effectiveness.

Before the 2000s, digital media have had a limited impact on environmental information and communication. Until the end of the 1980s, in fact, computer networks mainly concerned tech companies, armies, and the scientific community, with the public having little or no interest in them. Even with the advent of the World Wide Web and with the increasing accessibility of home computers and connections during the 1990s, the information retrieval still reflected a top-down structure and followed a "navigational" path, being filtered by search engines and limited at few institutional websites (Rose and Levinson 2004). Accordingly, digital media acted similarly to traditional media, providing people with generic environmental news.[2]

A more relevant shift towards digital ecology happened around 2004, with the development of the so-called web 2.0, a renewed Internet architecture that encouraged and simplified user-generated content. As blogs, wikis, and social networks did not require any advanced computer skills, many more people could now upload their own resources and share it among peers and strangers, turning the information structure into a bottom-up model featured by co-creation, dialogue and prosuming dynamics. For ecology, this opened a myriad of possibilities, gradually turning

[2] Traditional media, however, have had a profound influence in setting the environmental agenda (see Anderson 1997).

digital media from informational devices into participatory tools (see Mol 2008; Anderson 2014). Online forums or social media groups, for instance, allowed setting up protests or exchanging "sustainable life hacks" within the environmentalist communities. As the ANT scholar and political theorist Noortje Marres (2012, 74-77) points out, this kind of information are calls to environmental action that materialize participation according to the pragmatist motto "the more invested, the more engaged". From an environmental point of view, this particular use of digital media aims at co-articulating the "the amplification of costs, efforts, disruptions, as a way of documenting the 'costs' of environmental change" (Marres 2012, 77). Nonetheless, digital ecology and material participation also respond to different and more problematic co-articulations. In the field of nature conservation, for example, many NGOs and environmental institutions extensively exploited social media to enhance their projects (see Arts et al. 2015) by stimulating users' online engagement in order to collect more data through crowdsourcing and citizen science or to raise more funds through crowdfunding. Turning online engagement into offline activities with concrete implications on the physical environment, however, might lead to a "nature 2.0" (Büscher 2016) which suffers of spectacularization, subjection to neoliberal policies and slacktivism. The latter, in particular, represents a problematic and often useless or even harmful kind of participation, which responds to the liberal logics of the "minimization of the effort" and of the "involvement-made-easy" (Marres 2012, 65-71).

Yet, digital media materialized environmental participation in even more profound and paradoxical ways that sink their roots back to the emergence of the Internet imaginary (Flichy 2007). During the 1990s, a wide use of metaphors featured the public and political debate about digital media, depicting the Internet as a 'digital library', a 'cyberspace', or 'information highways' (Stefik 1996; Bory 2020). Besides feeding high expectations in terms of democracy, knowledge and wealth, the "digital sublime" (Mosco 2004) also caught the environmentalists' attention. Several scholars, companies, politicians and institutions explicitly juxtaposed environmental sustainability, which emerged as a public discourse in those same years, with the opportunities deriving from the Internet in terms of dematerialization (Camorrino 2018). Still today, emails, e-commerce and smart working, to cite just a few digital applications, are often promoted as effective tools for lowering energy and resources consumption. At the end of the 2000s, sharing economy platforms such as Blablacar (2006), Airbnb (2007) and Uber (2009) took a further step towards material participation. Mediating between supply and demand of underused assets through their websites or mobile apps, these companies often magnified the supposed environmental benefits deriving from using their services. An extensive literature, however, proved that all these assumptions were too optimistic, finding out that digital ICTs entail direct, indirect, and systemic rebound effects offsetting their supposed benefits

(Plepys 2002; Gossart 2015).

From an ANT perspective, digital ecology seems to represent an encouraging trend towards environmental sustainability. Acknowledging technology as a moral tool (Verbeek 2011) with an (ecological) agency of its own, digitization of ecology seems to hold Latour's call to "turn our exclusive attention away from humans and look also at nonhumans (…) the hidden and despised social masses who make up our morality" (Latour 1992, 227). Envisaging strong allies in non-human actants such as digital devices, systems and infrastructure, digital ecology might overcome the artificial dichotomy between culture and nature that features both ecological modernization and deep ecology. Nonetheless, digital ecology cannot rely on technology alone. Rather, to succeed in its ecological purpose and to avoid techno-solutionism, it needs to be part of a stronger actor-network, made up of both humans and natural non-humans. Emails and electronic documents alone cannot reduce paper usage if workers are not educated to their proper use; e-commerce or smart working alone cannot reduce air pollution if deforestation does not slow down drastically; and home sharing platforms alone cannot lessen resource waste if they gentrify entire cities. While dematerialization and slacktivism often present themselves as self-sufficient strategies, online environmental communities exploit interconnections and alliances, by connecting people each other, funding associations' projects, educating about biodiversity or sustainable living. These few examples help to point out that digital ecology, to be effectively sustainable and not to fail, should recruit as many allies as possible and build its own context (Latour 1996, 133-134), co-articulating environmental participation in broader terms, rather than limiting it to the technological register.

4. Ecologizing Digital Media

4.1 Greening strategies, from green it to green web

So far, by talking of digital ecology, we addressed environmental issues as a matter of digital technologies, with the latter affecting both our knowledge of the environment and attitudes towards it. We now attempt to reverse the relationship, enquiring whether and how environmental concerns (could) shape digital media's development and use. The reversal might seem abrupt, but the idea of dematerialization we have just gone through is a good case in point.

Besides presenting digitization as a self-sufficient and environmentally sound strategy, the dematerialization myth conceals the multiplication of devices it implies and their materiality. Even if all previous media industries have had profound ecological costs (see Maxwell and Miller 2012, 42-64), none of them embodied the "materiality paradox" (Schor and

White 2010, 40-41) as much as the digital one. As Balbi and Magaudda (2018, 8) point out, "contrary to the argument of dematerialization, digitization has encompassed an explosion of new hardware dedicated to reproducing and storing contents: from computers to telephones, DVDs to USB sticks, MP3 readers to cameras, to cite just a few. (…) The digitization process has actually stimulated the dissemination of material devices". The production, use, and disposal of digital artefacts and infrastructure involve an intensive use of energy and harmful resources, whose ecological impact is controversial but definitely growing. In 2007, ICTs were estimated to be responsible for 1% of global greenhouses gas emissions; in 2018, the value increased to 3.6% with it being projected to grow to 14% by 2040; of these emissions, devices currently account for the 31%, and infrastructures (data centres and communication networks) for the remaining 69% (Belkhir and Elmeligi 2018). If the IT sector was a country, it would rank third globally for electricity consumption (Cook 2017). Also, electronic waste is ever increasing: while in 2014 it amounted to 44.4 million tons, in 2019 it grew up to 53.6. Moreover, its vast majority (82.6%) is not documented and is being dumped improperly or even illegally in developing countries (Forti et al. 2020), causing enormous damages to the population and to the environment. Such ecological costs collide with the possibilities implied in dematerialization. As Luciano Floridi points out: "the overall result is that we are taking a technological gambit: we are counting on the fact that ICTs benefit the environment more significantly and quickly than they actually harm it, and that there is enough time for such a gambit to pay back" (Floridi 2014, 213). However, besides its assessment and quantification, ICTs' environmental impact acquires a more specific sociological relevance when observing how it affected the evolution of digital artefacts. In particular, from a SCOT perspective, digital media greening seems to reflect an interpretative flexibility involving different actors, strategies and values (Bijker et al. 1987).

While the public has been unaware of it for a long time, ICTs' environmental impact is a concrete and long-standing issue for producers and political institutions. Tech companies, in particular, have always been sensitive towards energy efficiency, as it goes hand in hand with devices' miniaturization and simultaneous increase in computational power. This process, which famously aroused the interest of Intel's co-founder Gordon Moore already in 1965, was fraught of economic opportunities and paved the way to the personal computers industry, disclosing an extremely valuable market. In 1992, computers energy efficiency became a subject for the U.S. Environmental Protection Agency program *Energy Star*. Launching its label to promote and certify hardware's energy performances, the EPA stimulated the emergence of an entire R&D sector, the so-called Green IT or green computing, which would have soon developed software solutions like screensavers and stand-by modes. In 2002, two European directives concerning hazardous substances and e-waste (2002/95/EC; 2002/96/EC) put another building block for digital media's

greening. By restricting the use of lead, mercury, cadmium, and other chemicals, and by introducing producers' responsibility for devices disposal, these measures stimulated eco-design innovations and facilitated practices such as computers refurbishing and recycling. Today, given their overwhelming carbon emissions, greening data centres represents the most crucial challenge for the so-called Green Web. As most players in the big tech industry are pledging to become carbon neutral within a decade (The Guardian 2020a; The Guardian 2020b), they are increasingly powering server farms with renewable energy and displacing them in remote locations or even beneath the sea to favour their natural cooling (Microsoft 2020).

Introducing energy and toxicity issues into computer engineering from the early 1990s, ecology has been affecting for at least thirty years the production of digital devices and infrastructures whose current technical shape and organization, somehow, incorporate environmentally sound solutions. Digital media's greening, however, is not yet a closed and stabilized process, as it is also following some divergent paths. Social practices like those encompassed by repair cafes, swapping communities, or the open source movement's aim at extending devices' life cycle and at resisting planned obsolescence through software and hardware manipulation (Jackson 2014). While Green IT combines ecology and linear economy, these social practices embrace very different values, supporting informal and circular economies and posing an obstacle to digital media's traditional market. Still from a SCOT perspective, hackers, activists, and hobbyists seem relevant social groups struggling for their own interpretation of digital devices and technological framework (Bijker et al. 1987). In this sense, the development of modular design for laptops and smartphones reflects an interpretative flexibility that might lead toward a more radical eco-design of digital media, taking into account not only their technical properties but also the social practices they can encompass. Looking at infrastructures, a particularly meaningful example of social greening is represented by Ecosia, a web search engine that, from December 2009 to October 2020, has planted more than one hundred million trees all over the world thanks to its users' online searches. As a social business whose mission is to build a greener Internet, Ecosia devolves part of its advertising revenues to offset its emissions through reforestation projects. The company states to be more than "carbon neutral" and that its website "actively remove[s] CO2 from the air" thus mitigating the effects of climate change (Ecosia 2019). Stating whether this is true or not would be a pointless operation, given how complex, hypothetical, and arbitrary environmental assessments are. Rather, recalling ANT and the previous section, what is mostly interesting about Ecosia is that it pursues digital media's greening by building on a network made of individuals, companies, advertisers, associations, digital infrastructures, devices, and natural entities such as trees.

4.2 Mediascapes and the need for a digital sustainability

As a polysemic expression, the ecologization of digital media also pertains to another, very different and twofold process, i.e., their increasing presence into the physical space and their simultaneous development into informational environments. While the previous section looked at green media through the lenses of SCOT, the focus is now on mediascapes (Appadurai 1990; Casetti 2018) or also ecomedia (Parisi 2019, 37-46), meant as both hypermediated environments and environmental media. Illustrating these concepts and their implications through Media Ecology, digital sustainability could be suggested as a convenient strategy to counter digital pollution, both in its environmental and communicative meaning.

All media – whether they are old or new, analogical or digital – exist as material artefacts that act upon a physical space, transforming it and giving it a temporary or permanent identity. Writing, for example, made archives possible; the printing press gave shape to modern libraries; Lumières' *cinematographe* brought cinema rooms and, later on, drive-ins; billboards continuously change the urban landscape, and television deeply affected the domestic space. Thus, when a medium, or a set of media, defines the essence and the practices of a place – be it a phone box, a game room, or a whole city – we then have a mediascape (Casetti 2018, 118). What is peculiar about digital media is that by enhancing the process of multi-media convergence (Jenkins 2006), they allowed traditional media to migrate into digital devices, giving life to new and hybrid mediascapes. Today, for instance, one can watch a movie in a cinema room as well as at home or on a bench in the street; similarly, one can purchase a music album in a specific store or while eating in a restaurant. The list of examples might be endless. As Casetti (2018, 131, my translation) points out, "even if technologies seem to become rapidly obsolescent, media, today, tend not to die: rather, they relocate. (…) Moving, a medium create a new kind of situation which generates a new mediascape". Over the last decade, because of a huge increase in mobile connectivity and digitized mobilities (Urry 2007), digital technologies filled the environment with informational flows, creating new spaces and reconfiguring old ones. In this sense, digital technologies are deeply ecological.

Even more important, however, is that digital technologies, thanks to multimedia convergence and connectivity, act as a gate to mediated environments, thus becoming virtual environments themselves. Media as environments, referring once again to Postman's powerful words, seems to be no longer a mere metaphor. Digital media's development in terms of informational environments is attested by the words we use when talking of them: *platforms, resources, surfing, web, browser, explorer, windows, cloud, drive* are just few examples explicitly recalling natural elements or spaces of action. Also, use of digital technologies is ever increasing: in 2019, the average global time spent per day on the Internet was 6 hours

and 42 minutes (We are social 2020). The reason why we spend more time on digital media than in real places like theatres, stores, parks, or museums is, at least in part, that through the same technology we can access to increasingly accurate representations of those places. Digital media are deeply ecological in this sense too. Such an intensive use requires to draw data from the Internet, but also to put a huge volume in. Depicting the extent of datafication, Floridi (2014, 13) reports that humanity had accumulated approximately 12 exabytes of data in the course of its entire history until the commodification of computers, but (…) it had already reached 180 exabytes by 2006. (…) The total grew to over 1600 exabytes between 2006 and 2011, thus passing the zettabyte (1000 exabytes) barrier. This figure is now expected to grow fourfold approximately every three years, so that we shall have 8 zettabytes of data by 2015.

These forecasts were extremely reductive. In 2018 alone, the world produced 33 zettabytes of data, with an expectation of growth up to 175 ZB in 2025 (Reinsel et al. 2018, 6). Collecting, storing and accessing this information, of which the overwhelming majority is redundant, has huge ecological costs, as illustrated in the previous section. Nonetheless, it also has social costs: data breaches, mass surveillance, online frauds, hate speech, illegal content, and viral fake news, to cite just a few critical examples, are a kind of communicative and symbolic pollution (Floridi 2020, 71-77) that depends on datafication and, at the same time, contributes to it. These issues are often addressed in technical or institutional terms, assuming digital media as mere instruments and asserting that it would be enough to improve cyber-security, to design new privacy policies or to develop better algorithms. From a ME perspective, instead, it seems more and more necessary to develop a digital sustainability strategy as strong and binding as the environmental one, but hopefully more effective. Increasingly fulfilling and representing the environment, digital media can no longer be considered as mere tools. Rather, we should acknowledge, protect and safeguard them as real environments, limiting the amount of resources to withdraw and to spill over them. This sort of digital e-nvironmentalism (Floridi 2014, 217-220) could take more or less complex forms. It might result, for example, in a digital transnational governance to take digital infrastructures away from private interest, or it could counter irresponsible feeding of algorithms through financial disincentives. Also, digital education programs could contribute, explaining that a clear and neat demarcation between online and offline is no longer possible (Boccia Artieri et al. 2017), and that we rather live an "onlife" experience taking place into an "infosphere" (Floridi 2014, 25-86) in which every action has consequences on the real environment. Educating and struggling for a digital sustainability strategy that, by involving individuals, institutions, companies, devices, and natural entities, could finally consider virtual environments just like real and concrete environments is a crucial challenge for the next years. Ecologizing digital media, in this sense, is not an accomplished process but a goal to pursue.

5. Conclusions

By adopting an STS-oriented approach, the relationships between digital media and the environment show up in all their complexity, going far beyond the impact issue. Digital ecology and ecological media emerge as crucial concepts that shed light on both the ecological crisis and the excesses of digitally mediated societies.

Digitization of ecology reconfigured our knowledge of the environment but at the same time raised new epistemological and political challenges. Environmental sciences benefited from digital media in terms of data collection but not in terms of coherence, feeding lasting controversies. Digital ecology also provided us with great opportunities and tools to live more sustainably and to take part into the ecological crisis. Participation, though, should not be restricted to the technological register. Rather, recruiting human, technological and natural actors, digital ecology could avoid some of its most common side effects. Among these, the environmental impact of digital devices and infrastructures represents an impelling issue.

ICTs' huge ecological costs allows to reverse the relationship and to enquire whether and how ecological concerns affected digital media's development and use. On one side, the ecologization of media is an ongoing process, given that several socio-technical innovations are in place to green digital technologies, affecting their evolution each in a different way. On the other side, though, ecologizing digital media is a goal to pursue. Even if digital technologies increasingly present themselves as mediascapes affecting our lives, it seems that our society is still reluctant in considering them likewise natural environments. A digital sustainability strategy inspired by the environmental one could limit the excessive resource drawing and spilling over, thus reducing digital technologies' environmental costs as well as the growing threats they pose to individual and social life.

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