Toin University of Yokohama
Research Bulletin, No.45, Dec. 2021

Articles

Ecological Transition from 'Red AI' to 'Green AI' on the Move:

Tackling Environmental Complexity with Super Intelligence

TAKEMURA Noriyoshi

(Received Date: Sep. 12, 2021)

I. Introduction

Artificial Intelligence (AI) will help us to solve some of the world's biggest challenges, they say, from treating chronic diseases to fighting climate change. However, public discourse on AI systematically avoids considering environmental costs of AI. Artificial Intelligence runs on technology, machines, and infrastructures which deplete scarce resources in their production, consumption, and disposal, thus increasing the amounts of energy in their use, and exacerbate problems of waste and pollution. It also relies on data centers, which demands impressive amounts of energy to compute, analyze, and categorize. In order to tackle the climate emergency, the environmental problems generated by AI must be addressed.

There is now incontrovertible evidence that the accelerating rise in the earth's temperatures and its associated environmental impacts, which begins with the emergence of an industrial capitalist order reliant on fossil fuels, has initiated a new phase of human and geological history: the Capitalocene rather than the more common term Anthropocene. Communication systems are playing a pivotal role in the Capitalocene. They are central and contested spaces for information and debate, and are the primary arenas promoting destructive hyper-consumption. Communication systems are also constituted by material infrastructure and devices that deplete scarce materials and energy resources and generate pollution and waste. The proliferation of digital media under conditions established by the globalization of neo-liberalism has exacerbated the negative environmental impacts of communications.

The computational costs of state-of-the-art AI research has exponentially increased in recent years. This trend, denoted Red AI, stems from the AI community's focus on accuracy while paying attention to efficiency. Red AI leads to a surprisingly large carbon footprint, and makes it difficult for academics, students, and researchers to engage in deep learning research. An alternative is Green AI, which treats efficiency as a primary evaluation criterion alongside accuracy. Green AI research will decrease AI's environmental footprint and increase its inclusivity. The term Green AI refers to AI research that yields novel results while taking into account the computational cost, encouraging a reduction in resources spent.

TAKEMURA Noriyoshi: Professor, Faculty of Law, Toin University of Yokohama. 1614 Kurogane-cho, Aoba-ku, Yokohama 225–8503, Japan

As smart cities are underpinned by our ability to engage with our environments, analyze them, and make efficient, sustainable and equitable decisions, the need for a 'Green AI' approach is intensified. The Green AI concept, as an enabler of the smart city transformation, offers the opportunity to move away from purely techno-centric efficiency solutions towards efficient, sustainable and equitable solutions capable of realizing the desired urban futures. The aim of this perspective is twofold: first, to highlight the fundamental shortfalls in mainstream AI system conceptualization and practice, and second, to advocate the need for a consolidated AI approach, Green AI, to further support smart city transformation.

In this article, following problems are cleared and deliberated: mythologizing AI and omitting the environment; communications and Capitalocene; AI's environmental footprint and its inclusivity; Green AI toward an efficient, sustainable and equitable technology.

II. Mythologizing AI and Omitting the Environment

In this section, following the research by Benedetta Brevini (Brevini, 2020), AI's environmental costs are addressed.

The recent acceleration of AI developments (data mining and computational evaluations of persons and corporations) has far-reaching environmental costs. It is critical to a complex of interlinked innovations in technology, machines and infrastructures. These material apparatuses and technologies deplete scarce resources in their production, consumption and disposal, thus increasing the amounts of energy expended in their use and exacerbate problems of waste and pollution. AI also relies on data centers that demand impressive amounts of energy to compute, analyze, and categorize with grave consequences for the climate emergency (Brevini, 2020: 1–2).

1. Promises of AI

Despite the existential threat of climate change emerging as humanity's greatest challenge, the environmental costs of AI, algorithms, and data analytics are not accounted for when developing new policies on AI. There are philosophical and historical reasons for this deafening silence on AI's environmental impact. Scholars in critical political economy of communication have showed how discourses around digital technologies have historically been constructed as modern myths decorated with allusions to utopian worlds and new possibilities (Brevini, 2020: 2).

This framing of AI as the magic tool to rescue the global capitalist system from its dramatic crises obfuscates the materiality of the infrastructures that are central to the environmental question that has been so consistently and artfully ignored. A recently released report, *Harnessing Artificial Intelligence for the Earth*, reiterates that the solution to the world's most pressing environmental challenges is to harness technological innovations—none more so than AI. "The intelligence and productivity gains that AI will deliver can unlock new solutions to society's most pressing environmental challenges: climate change, biodiversity, ocean health, water management, air pollution, and resilience, among others" (World Economic Forum, 2018: 19). This bold vision, insistently argued by advocates as if it were common sense makes once again no reference to the materiality of AI and its environmental consequences (Brevini, 2020: 2–3; Rodhain, 2019; Groupe ÉcoInfo, 2012).

Unfortunately, the carbon footprint of AI-powered algorithms is not only largely absent from public discourses on AI developments, but often it is neglected in the academy (Brevini, 2020: 3).

2. Environmental Costs of AI Development

Research in the field of communication systems, technology, and the environment is sparse (Brevini *et al.*, 2017; Maxwell *et al.*, 2012). However, a new study published in June 2019 by the College of Information and Computer Sciences at University of Massachusetts, Amherst has for the first time attempted to quantify the energy consumed by running AI programs. In the case examined by the study, a common AI training model in Linguistics can emit more than 284 tonnes of carbon dioxide equivalent (Strubell *et al.*, 2019). This is comparable to five times the lifetime emissions of the average American car. It is also comparable to roughly 150 return flights from London to NYC. And AI models' energy consumption does not stop after training but extends to its utilization. Meanwhile, the converged communication and computational systems upon which AI relies generate a plethora of environmental problems of their own, most notably energy consumption and emissions, material toxicity, and electronic waste (Brevini *et al.*, 2017). According to the International Energy Agency (2017) if the energy demand continues to accelerate at this pace, even just the residential electricity needed to power electronics will rise to 30% of global consumption by 2022, and 45% by 2030 (Maxwell, 2015; Brevini, 2020: 3).

AI relies on data to work. At present, cloud computing eats up energy at a rate somewhere between what Japan and India consume in their national energy markets (Greenpeace, 2017; Murdock *et al.*, 2019). Today, data centers' energy usage averages 200 TWh each year (International Energy Agency, 2017) more than the national energy consumption of some populous countries such as Iran. Furthermore, most data centers require large, continuous supplies of water for their cooling systems, raising serious policy issues in places like the US where years of drought have ravaged communities (Mosco, 2017). One of the latest reports that estimated the carbon footprint of ICT (including servers' networks and devices) sketches an even more concerning picture. The energy consumption of digital technologies is increasing by 9% a year, and already represents 3.7% of global greenhouse gas emissions (Shift Project, 2019). This percentage of emissions is almost double that of the aviation industry, currently at 2% (Brevini, 2020: 3–4).

Finally, when communication and computational machines are discarded they become electronic waste or E-waste, saddling local municipalities with the challenge of safe disposal. This task is so burdensome that it is frequently offshored, and many countries with developing economies have become digital dumping grounds for more privileged nations (Brevini *et al.*, 2017; Brevini, 2020: 4).

3. Another Black Box, Not Green

Ecological criticism has established that it is the violence and inequality of capitalism that have ultimately caused the ecological emergency we now face. Adding to this view, the acceleration of the impact of human interventions on the Earth's ecosystems identified by climate research coincides with significant rushing and development of communication and computational systems (Brevini *et al.*, 2017). This has in turn drastically accelerated our consumption of raw materials and energy, rapidly compounding our global environmental challenges. Thus, in addition to understanding the opaqueness of black box algorithms, we must also shine light on their environmental costs. Quantifying and considering the environmental costs and damages of the current acceleration of algorithm-powered AI, as well as the mythological machine that drives and protects its growth, will be one of our greatest hurdles in confronting the climate emergency (Brevini, 2020: 4).

As AI necessitates more and more computing capabilities, measuring the carbon footprint of computing and disclosing this information would be a first step in the right direction. One solution could be to offer a transparent account of the carbon footprint of AI-powered devices in the form of a 'Tech Carbon Footprint Label' to raise awareness and adequately inform regulators and the public about the implications of the adoption of each piece of smart technology. Pasquale (2015) says that curbing the scope and power of black box decision making is essential. Black Boxes are not Green (Brevini, 2020: 4).

III. Communications and the Capitalocene

In this section, following the research by Graham Murdock and Benedetta Brevini (Murdock *et al.*, 2019), negative environmental impacts of communication systems in contemporary capitalism are examined.

As there is the linkage between communications and contemporary capitalism, we need an inquiry for the field of political economy of communication. Two essential points of connection need to be considered. Firstly, as profit-generating enterprises dependent on advertising revenues, the major popular media carry substantial volumes of content that insistently promote practices of hyper-consumerism which fuel the ecologically destructive pursuit of economic growth. Secondly, as proliferating assemblages of material devices and infrastructures, communication systems deplete scarce resources in their production, consume increasing amounts of energy in their use, and exacerbate problems of waste and disposal (Murdock *et al.*, 2019: 52).

The appropriation of communal resources by commercial enclosure has been central to the consolidation and expansion of capitalism from the outset. Over the last four decades, however, this process has intensified and extended under the intersecting impact of neo-liberal economic globalization and the rapid roll-out of digital media. This has initiated a new era in humanity's relation to the natural world. The central role of communications in organizing every aspect of economic and social life places a particular responsibility on media scholars to take questions of ecological sustainability fully into account in formulating both immediate policy interventions and longer-term proposals for reorganization. Here, the critical political economy of communication can play an indispensable role by insisting that changes in the organization of communication systems and the reduction of their environmental impacts entail prior understandings of the capitalist market fundamentalism and its global reach. This provides an essential corrective to the presentism and technologically centered discourse that saturates much public discussion on new media (Murdock *et al.*, 2019: 53).

1. Capitalism and Earth System: Acceleration, Disruption and Communications

According to Moore, the idea of the Anthropocene denies the central role played by the violence and inequality of capitalism and presents the planet-wide ecological devastation it has caused as the responsibility of all humans (Moore, 2018). Once we recognize this, he argues, we need to move from talking about "living in the *Anthropocene* — the 'age of man' " to acknowledging that we are "living in the *Capitalocene* — the 'age of capital' — the historical era shaped by the endless accumulation of capital" (Moore, 2017: 596; Moore, 2016). He develops this argument in his model of the 'web of life' that the history of destructive human interventions in the earth system cannot be divorced from analyses of the successive transformations of capitalism (Moore, 2015). The present era is characterized as the Capitalocene rather than the Anthropocene (Murdock *et al.*, 2019: 56; Lewis *et al.*, 2018).

Someone using a smart phone, tablet or digital personal assistant is contributing to emission and energy depletion when they use these devices however. Consequently, the organization of media consumption remains a key link in the chain of environmental impacts. But a substantial portion of total impact is embodied in these machines and their design before they are purchased. Consequently, the use of material is determined by the manufacturers, and this places the primary responsibility on producers. The ideology of consumer sovereignty deliberately fails to take account of the massive corporate investment in advertising and marketing devoted to sustaining and directing consumption, and the increasingly central role played by planned obsolescence in forcing consumers to upgrade or replace commodities on an accelerating basis. These processes have played a central role in the recent history of relations between capitalism and communications (Murdock *et al.*, 2019: 57).

Recent accelerations in the impacts of human interventions on the earth system identified by climate and geological research coincide with significant extensions in communication systems and the consequent increased demands on material resources and energy. From the mid-1970s, during the second acceleration in the impacts on man-made interventions in earth systems, the progressive availability and application of digital communications intersect with the consolidation of neo-liberal capitalism to form a fateful combination of destructive forces. It is only by placing the rise of digital media firmly in the context of the wider transformation of capitalism and its global articulations that the timeline of the most recent escalation in global temperatures can be properly interpreted. As indicated previously, this escalation has been identified by climate research and confirmed by the formation of new geological strata comprised of plastic residues and other ‘techno fossils’ (Murdock *et al.*, 2019: 58).

2. Saturated Promotion and Toxic Materials: Hyper Consumerism, Devices and Infrastructures

Addressing capitalism’s structural crisis of the mid-1970s required a fundamental reorganization of both production and consumption (Streeck, 2016). Neo-liberal globalization saw increasing numbers of routine assembly and clerical jobs outsourced to low income economies overseas, and an accelerating shift from heavy industry to services within advanced capitalist societies accompanied by increasing casualization and precarity and attacks on trade unions. At the same time, restoring profitability required a major extension of consumption (Murdock *et al.*, 2019: 64–65).

In addition, as agencies of hyper consumption, on-line platforms offered three other advantages over traditional commercial media. Firstly, accumulated amounts of personal data harvested from users provided raw information that could be converted into increasingly fine-grained mapping of markets and personalized appeals. Secondly, the introduction of smart phones that operate as both platforms for promotion and payment devices has radically reduced the time consumers have to reconsider purchasing decisions. No more counting out coins and notes or keying in credit card security numbers. Simply swipe your phone across the pay point. Thirdly, social media platforms have been able to harness the horizontal, peer-to-peer, organization of the internet. From the ubiquitous clicks on likes and smiling emoticons to the ranks of young influencers on YouTube talking about and demonstrating products, including digital games and cosmetics, social media have comprehensively incorporated networks of friendship and peer recognition into their promotional portfolios (Murdock *et al.*, 2019: 65–66).

The negative environmental impacts of commercial social media derives from their incessant promotion of commodities and lifestyles that depend on accelerated cycles of obsolescence and disposal and which make increasingly unsustainable and destructive calls on resources and energy in their production and use. And, most fundamentally, their own business strategies are primary drivers of this process. One must critique the varieties of exploitation entailed in the labour processes around the making of digital devices and services. Fewer have travelled further down the production chain to detail the environmental costs of extracting the raw materials and generating the energy digital media require or to trace the trails of pollution and waste incurred in transportation, use and disposal (Murdock *et al.*, 2019: 67).

At the same time, rapid expansion of the internet of things and the application of artificial intelligence and robotics to an increasing range of manufacturing and service systems will massively increase the volume of data needing to be transmitted, analyzed and stored. These escalating communication demands could command a quarter of the world's total electricity supply by 2025 (Murdock *et al.*, 2019: 68).

3. Interventions and Transformations

The transformation of contemporary communication under the double impact of neo-liberal economic policies and digital innovation lends new impetus and urgency to both long standing issues around ownership, control and performance and emerging questions around materials and energy. Faced with an accelerating climate catastrophe, how we organize our major channels of public communication as cultural and material complexes matters more than ever (Murdock *et al.*, 2019: 69).

The materials employed in constructing media infrastructures and devices and the labour process entailed in their production and distribution also pose urgent questions. Critical political economists need to be at the forefront of mobilizations for alternative materials for batteries and other vital components. They need to support struggles around the labor conditions under which communications devices are manufactured and transported, and around concerns of reuse, recycling and reducing waste. Arresting the acceleration of the planned obsolescence which is driving hyperconsumption requires concerted efforts to revivify systems of repair while replacing plastics, most of which are made from petrochemicals. These are by-products of the oil industry, which provide them with a substantial additional source of profits. Stopping this profit stream is an essential step in reducing avoidable waste and pollution. Additionally, the construction and packaging of communications devices needs to move rapidly to renewable and biodegradable materials (Murdock *et al.*, 2019: 73).

Foregrounding the material bases of communication systems propels debate around their future constitution and governance some way beyond the established concerns of media research and policy. The need for this extended focus is further underlined by Google's acquisition of the major artificial intelligence corporation, Deep Mind, and Facebook's decision to launch a proprietary crypto-currency, Libra. These moves compound two developments as posing major problems of environmental impact. Firstly, the expansion of smart machines and the internet of things will lead to significantly increased calls on materials and on energy. Secondly, creating a new source of finance outside the banking system, with access to Facebook's massive user base, will reinforce hyper-consumerism by boosting instantaneous purchases of commodities displayed online and expanding personal debt. As critical researchers we have two choices. Either we say these developments and their consequences are beyond the bounds of our expertise. Or we match the ambition of the leading digital players and look to forge new collaborative alliances across all the relevant specialisms as a basis for building a comprehensive analysis and programme of intervention (Murdock *et al.*, 2019: 74).

The Capitalocene presents us with a double crisis: an accelerating climate and environmental catastrophe caused by intensified capitalist interventions in the earth system; and a deepening social crisis of widening inequalities of wealth and income combined with sustained processes of exploitation and dispossession set in motion by the aggressive pursuit of neoliberal economic policies. As a consequence, any proposal for radical change must guarantee as a minimum, both an equitable allocation of the resources that support well-being and social agency and an insistence that ecological ceilings for sustainability are not exceeded (Murdock *et al.*, 2019: 74).

In short, the critical political economy of communication has an indispensable contribution to make in devising and pursuing this conception of a sustainable future by demonstrating the foundational roles played by communications systems in organizing the economic and social relations that impact on the earth system, by rethinking the relations between economies of public goods and commoning as the basis for viable alternatives to commodification, and by pressing for practical changes to prevailing structures that will advance both ecological sustainability and economic and social justice. It is a formidable challenge but also an unprecedented opportunity (Murdock *et al.*, 2019: 76).

IV. Green AI vs. Red AI: AI's Environmental Footprint and its Inclusivity

In this section, following the research by Roy Schwartz, Jesse Dodge, Noah A. Smith, and Oren Etzioni (Schwartz *et al.*, 2020), the recent trend of state-of-the-art AI research from red to green is considered.

AI research can be computationally expensive in a number of ways, but each provides opportunities for efficient improvements. Reporting the computational price tag of developing, training, and running models is a key Green AI practice. In addition to providing transparency, price tags are baselines that other researchers could improve on. However, the AI research community has paid relatively little attention to computational efficiency. In fact, the computational cost of high-budget research is exponentially increasing, at a pace that far exceeds Moore's Law. Red AI is on the rise despite the well-known diminishing returns of increased cost (Schwartz *et al.*, 2020: 56).

There are key factors that advocate the introduction of a simple, easy-to-compute efficiency metric which could help make some AI research greener, more inclusive, and perhaps more cognitively plausible. Green AI is part of a broader, long-standing interest in environmentally friendly scientific research. Computer science, in particular, has a long history of investigating sustainable and energy-efficient computing (Schwartz *et al.*, 2020: 56).

1. Challenges of Red AI

Red AI researches seek to improve accuracy through the use of massive computational power while disregarding the cost—essentially buying stronger results. Yet the relationship between model performance and model complexity, measured as number of parameters or inference time, has long been understood to be at best logarithmic. For a linear gain in performance, an exponentially larger model is required. Similar trends exist with increasing the quantity of training data and the number of experiments. In each of these cases, diminishing returns come at increased computational cost (Schwartz *et al.*, 2020: 56).

With the increasing costs of AI experiments, a natural economic motivation for developing more efficient AI methods has appeared. It might be the case that at a certain point prices will be too high, forcing even researchers with large budgets to develop more efficient methods. However, currently most effort is still being dedicated to accuracy rather than efficiency. At the same time, AI technology is already very expensive to train or execute, which limits the ability of many researchers to study it, and of practitioners to adopt it. Combined with environmental price tag of AI, more effort should be devoted toward efficient AI solutions (Schwartz *et al.*, 2020: 58).

Now, awareness to the cost of Red AI have to be raised and researchers who use such methods have to be encouraged to take steps to allow for more equitable comparisons, such as reporting training curves. The AI community have to be encouraged to recognize the value of work by researchers that take a different path, optimizing efficiency rather than accuracy (Schwartz *et al.*, 2020: 59).

2. Prospects of Green AI

Green AI researches yield novel results while taking into account the computational cost, encouraging a reduction in resources spent. Whereas Red AI has resulted in rapidly escalating computational costs as well as carbon emissions, Green AI promotes approaches that have favorable performance/efficiency trade-offs. If measures of efficiency are widely accepted as important evaluation metrics for research alongside accuracy, then researchers will have the option of focusing on the efficiency of their models with positive impact on both inclusiveness and the environment (Schwartz *et al.*, 2020: 59).

Recently efficient machine learning approaches have received attention in the research community but are generally not motivated by being green. For example, a significant amount of work in the computer vision community has addressed efficient inference, which is necessary for real-time processing of images for applications like self-driving cars, or for placing models on devices such as mobile phones. Other methods to improve efficiency aim to develop more efficient architectures, starting from the adoption of graphical processing units (GPU) to AI algorithms, which was the driving force behind the deep learning revolution, up to more recent development of hardware such as tensor processing units (TPUs22) (Schwartz *et al.*, 2020: 60).

The examples here indicate the path to making AI green depends on how it is used. When developing a new model, much of the research process involves training many model variants on a training set and performing inference on a small development set. In such a setting, more efficient training procedures can lead to greater savings, while in a production setting more efficient inference can be more important. We advocate for a holistic view of computational savings which doesn't sacrifice in some areas to make advances in others (Schwartz *et al.*: 60).

In short, the vision of Green AI raises many exciting research directions that help to overcome the challenges of Red AI. Progress will find more efficient ways to allocate a given budget to improve performance, or to reduce the computational expense with a minimal reduction in performance. Also, it would seem that Green AI could be moving us in a more cognitively plausible direction as the brain is highly efficient (Schwartz *et al.*, 2020: 62; Villani *et al.*, 2018; Bordage, 2019).

V. Green Artificial Intelligence: Toward an Efficient, Sustainable and Equitable Technology for Smart Cities and Futures

In this section, following the research by Tan Yigitcanlar, Rashid Mehmood, and Juan M. Corchado (Yigitcanlar *et al.*, 2021), the Green AI as an efficient, sustainable and equitable technology is analyzed.

The growing concern over negative AI externalities and service failures proves the need for more ethical and regulated AI systems. Subsequently, in recent years, attempts to provide a more holistic perspective on AI have resulted in a number of new AI conceptualizations. These include 'responsible AI', 'ethical AI', 'explainable AI', 'sustainable AI', 'green AI' and the like, the aim of which is to ensure the ethical, transparent and accountable use of AI applications in a manner that is consistent with user expectations, organizational values, environmental conservation and societal laws and norms. Such renewed approaches to AI will help maximize the desired smart city outcomes and positive impacts for all citizens, while minimizing the negative consequences (Yigitcanlar *et al.*, 2021: 4).

1. Green AI Approach for the Flourishing of Humans and the Planet

The most common negative effects of AI on the environment include increases in electricity usage (computation and transmission power consumption) and the resulting carbon emissions, along with errors in critical decisions due to user and data bias. Given that global technology uptake is growing at an exponential rate, the impact of these externalities is expected to be immense. Just to give an example, cryptocurrency mining in recent years has led to increased energy consumption globally. These undesired externalities call for a sustainable approach to AI that adopts a green-based technological perspective, including switching to a sustainable AI infrastructure (Yigitcanlar *et al.*, 2021: 6).

The Green AI approach, which makes AI green and sustainable, requires a bias-free, inclusive, trustworthy, explainable, ethical and responsible approach to technology that aims to alleviate the developmental challenges of the planet in a sustainable way (Vinuesa *et al.*, 2020). This approach, which uses AI to solve sustainability challenges and in a more sustainable way, will also serve as an enabler of smart city transformation (Yigitcanlar *et al.*, 2021: 6).

2. Green Sensing, Communications and Computing

In order to aid in the development of Green AI both at the policy and the infrastructure level, the concept of 'green sensing' is introduced and defined as physical and virtual green sensing to enable triple bottom line (social, environmental and economic) sustainability. The definition proposes the development of methods and technologies to sense and measure social, environmental and economic sustainability. Sustainability is affected by challenges such as security, privacy, the safety of people, ethical standards and compliance, and so on, and therefore these are included in our definition of green sensing. These methods and technologies should be green in terms of their efficiency and energy usage. The data sensed through IoT and other media are usually transferred to a central location, such as a master node or a cloud computing center, for their analysis. An astonishingly large amount of energy is required to transfer data across networks. Naturally, a range of techniques have been developed to reduce data communication energy and improve network efficiency. In addition to reducing data generation through the various green sensing techniques mentioned earlier, various data pruning methods have been developed, such as using data compression to reduce communication and bandwidth requirements (Yigitcanlar *et al.*, 2021: 7–8).

Such an energy efficiency is a grand challenge in the design of large-scale computing systems, such as supercomputers and computational clouds. While AI algorithms consume large amounts of power, they can be used to reduce the energy requirements of computations while optimizing performance, thus allowing for the concept of green sensing and optimizations to be introduced into computing systems (Yigitcanlar *et al.*, 2021: 8).

3. Policy Directions for making AI Greener and Cities Smarter

In recent years there is a desire for a Green AI approach to further support smart city transformation and SDGs, because there appear fundamental shortfalls in mainstream AI system conceptualizations and practices (Yigitcanlar *et al.*, 2021: 8).

A perspective on the Green AI concept defines and elaborates on the concept, and discusses why a consolidated effort is needed in the area, including the benefits of a strengthened Green AI approach. The elaborations are supported by the literature from diverse disciplines, including computer, environmental and social sciences, and urban studies. It also discusses issues that relate to the development of digital infrastructure for Green AI. The intention is to discuss these infrastructural issues together with other high-level issues, and to provide a holistic overview such that different communities working in policy and infrastructure research can understand cross-disciplinary issues and collaboratively devise holistic and globally optimum solutions (Yigitcanlar *et al.*, 2021: 8–9).

Moreover, in order to aid in the development of Green AI, both at the policy and infrastructural levels, they introduce and define the concept of 'green sensing' as physical and virtual green sensing to enable triple bottom line (social, environmental and economic) sustainability. They highlight the importance of, and advocate the need for, the development of methods and technologies to sense and measure social, environmental and economic sustainability. This perspective piece makes an invaluable contribution to the emerging field of Green AI, as there is no scholarly literature that discusses the policy and infrastructural issues of the given topic in an abstracted way. It is important to gain a holistic understanding of the issues related to Green AI via a relatively succinct perspective piece, and presents prospective research and development directions (Yigitcanlar *et al.*, 2021: 9; Gailhofer *et al*., 2021; Van Wynsberghe, 2021).

Following remarks can be suggested, as it is highly important to have timely, effective and efficient government policy in place for making AI greener and our cities smarter (Yigitcanlar *et al.*, 2021: 9).

Firstly, there are colossal policy challenges in the way of making AI green. The most critical one is the need for governments to develop legal and ethical frameworks for AI and its use. Expanding on this issue, they list fairness and equity, accountability and legal issues, ethics, misuse protection, transparency and auditing, and digital divides and data deficits as the fundamental public and environmental policy challenges of AI. Another study disclosed "the primary AI ethical principles as follows: transparency, justice and fairness, non-maleficence, responsibility, privacy, beneficence, freedom and autonomy, trust, sustainability, dignity, and solidarity". These principles are critical to AI projects' ability to deliver the desired outcomes to all (Yigitcanlar *et al.*, 2021: 9).

Secondly, up until now, no country has passed an AI law yet, and only a small number of countries have attempted to introduce AI ethical frameworks and regulation guidelines, such as the European Union's AI ethics guidelines, intended to inform future regulation, and other examples include AI ethical frameworks in Australia, Germany, Singapore and the UK. The most popular existing practice for most governments seems to be adopting a 'wait-and-see' approach to AI ethics and regulations. Furthermore, in most cases, the existing ethics frameworks fail to serve their purposes, as they lack any reinforcement mechanisms (Yigitcanlar *et al.*, 2021: 9).

This renewed Green AI approach and capacity will also consolidate the efforts made to transform our cities into smart ones, and support the smart and sustainable development of our cities and communities. In other words, we need to put our best effort into making AI an efficient, sustainable and equitable technology for establishing smart cities and sustainable futures (Yigitcanlar *et al.*, 2021: 10).

VI. Conclusion

The scientific community must address ecological problems of AI because it concerns questions of ethics and transparency. AI is not immaterial. Natural resources being partly non-renewable, AI is a limited resource. We need a responsible use of AI. It is necessary to develop AI towards more frugal, limiting a resource use to the maximum. The deep learning and the quantity of data and calculation must be progressively replaced with less energy consuming AI. In order to end 'green wash' (Takemura, 2015), we need valuate the projects which integrate an energetic efficiency and demand the transparency of environmental impact of AI solutions. Uniting AI and ecological transition is a delicate mission, but this challenge could make an ecosystem honorable. Giving a sense to AI, the ecological revolution will be promoted. Currently an orientation of AI towards an advantage of equity, responsibility, and transparency is assisted. In this context, the environmental ethic of AI will be important essential objective. The ecological transition of AI is on the move.

[Notes]

1) This article is a part of research results of 'Research on North-South Integrated Global Green Criminology and Foundation of International Environmental Court 2019–2023'. This work is supported by JSPS KAKENHI Grant Number JP19K01353.
2) This article is also based on the paper prepared for the 2021 American Society of Criminology annual meeting held in Chicago, USA, 17–20 November 2021. But the author could not attend the meeting because of various restrictions of COVID 19.

[References]

Bordage, F. (2019). *Sobriété numérique: les clés pour agir*. Paris: Buchet Chastel.

Brevini, B. (2020). Black boxes, not green: Mythologizing artificial intelligence and omitting the environment. *Big Data and Society*, 7 (2): 1–5.

Brevini, B., and Murdock, G. (2017). *Carbon Capitalism and Communication: Confronting Climate Crisis*. London: Palgrave Macmillan.

Gailhofer, P., Herold, A., Schemmel, J. P., Scherf, C.-S., Urrutia, C., Köhler, A. R., and Braungardt, S. (2021). *The role of Artificial Intelligence in the European Green Deal*, Study for the special committee on Artificial Intelligence in a Digital Age (AIDA). Luxembourg: Policy Department for Economic, Scientific and Quality of Life Policies, European Parliament.

Greenpeace (2017). *Clicking Clean: Who is winning the Race to Build a Green Internet?*. Washington, D.C.: Greenpeace.

Groupe ÉcoInfo (2012). *Impacts écologiques des Technologies de l'Information et de la Communication: les faces cachées de l'immatérialié*. EDP Sciences.

Herweijer, C., Combes, B., Gillham, J. (–), *How AI can enable a Sustainable Future*. Microsoft and PwC.

International Energy Agency (2017). *Digitalization and energy*. IEA Publications.

Lewis, S. L., and Maslin, M. A. (2018). *The Human Planet: How We Created the Anthropocene*. Pelican Books.

Maxwell, R. (2015). High-tech consumerism, global catastrophe happening on our watch. (https://theconversation.com/high-tech-consumerism-a-global-catastrophe-happening-on-our-watch-43476)

Maxwell, R., and Miller, T. (2012). *Greening the Media*. Oxford: Oxford University Press.

Moore, J. (2015). *Capitalism in the Web of Life: Ecology and Accumulation of Capital*. London: Verso.

Moore, J. M. (ed.) (2016). *Anthropocene or Capitalocene? Nature, History, and the Crisis of Capitalism*. Oakland, CA: PM Press.

Moore, J. (2017). The Capitalocene Part I: on the nature and origins of our ecological crisis. *The Journal of Peasant Studies*, 44 (3): 594–630.

Moore, J. (2018). The Capitalocene Part II: accumulation by appropriation and the centrality of unpaid working/energy. *The Journal of Peasant Studies*, 45 (2): 237–279.

Mosco, V. (2017). The next internet. In: Brevini, B., and Murdock, G. (eds.). *Carbon Capitalism and Communication: Confronting Climate Crisis*. London: Palgrave Macmillan, pp.95–107.

Murdock, G., and Brevini, B. (2019). Communications and the Capitalocene: Disputed Ecologies, Contested Economies, Computing Futures. *The Political Economy of Communication*, 7 (1): 51–82.

Open.Studio (2021). *Intelligence Artificielle & Protection de l'Environnement: Le Paradoxe d'une Technologie Énergivore au Service des Défis Écologiqes de Demain*. Libre Blanc.

Pasquale, F. (2015). *The Black Box Society*. Canbridge, MA and London: Harvard University Press.

Rodhain, F. (2019). *La nouvelle religion du numérique: le numérique est-il écologique?* EMS Editions.

Schwartz, R., Dodge, J., Smith, N. A., and Etzioni, O. (2020). Green AI. *Communications of the ACM*, 63 (12): 54–63.

Shift Project (2019). *Learn ICT — Toward digital sobriety*. Report of the working group directed by Hugues Ferreboeuf. (https://theshiftproject.org/wp-content/uploads/2019/03/Lean-ICT-Report_The-Shift-Project_2019.pdf)

Streeck, W. (2016). *How Will Capitalism End? Essays on a Failing System*. London: Verso.

Strubell, E., Ganesh, A., and McCallum, A. (2019). Energy and policy consideration for deep learning in NLP. (https://arxiv.org/abs/1906.02243)

Takemura, N. (2015). Transnational Economic Crimes against Global Environment and Ecology: 'Janus-faced Greenwash' by Multinational-States-Complex and its Butterfly Effects. *NCCD-JAPAN*, 50: 21–41.

Van Wynsberghe, A. (2021). Sustainable AI: AI for sustainability and the sustainability of AI. *AI and Ethics*. (https://doi.org/10.1007/s43681-021-00043-6)

Villani, C., Schoenauer, M., Bonnet, Y., Berthet, C., Cornut, A.-C., *et al.* (2018). *Donner un sens à l'intelligence artificielle : Pour une stratégie nationale et Européenne*. Mission Villani sur l'intelligence artificielle, 2018, Yann Bonnet, Secrétaire général du Conseil national du numérique, 978-2-11-145708-9. (https://www.aiforhumanity.fr/). (hal-01967551)

Vinuesa, R., Azizpour, H., Leite, I., Balaam, M., Dignum, V., Domish, S., Felländer, A., Langhaus, S. D., Tegmark, M., and Nerini, F. F. (2020). The role of artificial intelligence in achieving the Sustainable Development Goals. *Nature Communications*, 11: 233 (https://doi.org/10.1038/s41467-019-14108-y)

World Economic Forum (2018). *Harnessing Artificial Intelligence for the Earth*. The World Economic Forum System Initiative on Shaping the Future of Environment and Natural Resource Security in partnership with PwC and the Stanford Woods Institute for the Environment.

Yigitcanlar, T., Mehmood, R., and Corchado, J. M. (2021). Green Artificial Intelligence: Towards an Efficient, Sustainable and Equitable Technology for Smart Cities and Futures. *Sustainability*, 13, 8952: 1–14.