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Editorial

Greening the Artificial Intelligence for a Sustainable Planet: An Editorial Commentary

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Artificial intelligence (AI) is one of the most popular and promising technologies of our time. While there is a clearer understanding on the role of AI in boosting the efficiencies at private companies, government agencies and urban management, there is ambiguity on the specific contributions of AI to environmental sustainability. In this editorial commentary: (a) the important role that AI could play in addressing global environmental sustainability challenges is discussed; (b) the need for a consolidated AI approach to support the efforts in addressing global environmental sustainability problems—e.g., meeting the global sustainable development goals, developing smart and sustainable cities and regions, and tackling the climate and biodiversity crises—is identified; (c) the emerging Green AI concept that offers a consolidated AI perspective that is an essential step towards global environmental sustainability is introduced; (d) the adoption of the Green AI approach by industry, government, and not-for-profit organizations for addressing environmental sustainability challenges of the planet and for improving the quality of lives of our societies in cities is advocated. The editorial commentary also introduces the contributions to the Special Issue on reviews and perspectives on smart and sustainable metropolitan and regional cities.

Our planet reached its maximum human carrying capacity with 3.5 billion people in 1970 [1]; where human carrying capacity is defined as "the maximum rates of resource harvesting and waste generation, the maximum load, that can be sustained indefinitely without progressively impairing the productivity and functional integrity of relevant ecosystems wherever the latter may be located" [2] (p. 203). Regrettably, over the last five decades, we continued the practice of rapid population and also urban and industrial growth beyond the limits of our planet's carrying capacity [3].

This carrying capacity overshoot, also coupled with the excessive human activity that is causing environmental degradation, resulted in a degraded carrying capacity state. These overshoot and degraded carrying capacities have been changing the climate and causing biodiversity losses at scale [4]. Biodiversity loss is inextricably linked to anthropogenic climate change that jeopardizes global ecosystems services, including agricultural, forest, marine, reef, costal, polar, mountain, island, and microbial ecosystems [5].

The unavoidable risk of facing catastrophic consequences, such as biodiversity collapse, has triggered some global initiatives with an aim of to slow down or reverse the existing growth processes. As the successor of the 2020 Millennium Development Goals, in 2015, United Nations (UN) adopted 2030 Sustainable Development Goals (SDGs), as the blueprint to achieve a more sustainable future for all [6]. UN's SDGs contain 17 goals that consist of 169 targets [7]. The same year, UN delivered a universal and legally binding climate change deal—i.e., The Paris Agreement on climate change [8]. In 2018, the Intergovernmental Panel on Climate Change (IPCC)—the world's most authoritative body on climate science—released its special report (i.e., Global Warming of 1.5 °C) revealing the impacts of 1.5 °C global warming on natural and human systems [9].

Additionally, 2019 European Green Deal provided action plans to boost the efficient use of resources by moving to a clean and circular economy, restore biodiversity, and cut pollution—2020 US Green Deal and 2021 The Biden Climate Plan also have similar

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goals [10]. The latest IPCC report, released in 2021, was a code red declaration for humanity, and a warning for "world leaders to drastically scale up their plans to curb carbon dioxide emissions if humanity is to avoid the worst consequences of a warming world" [11] (p. 8).

In an era that is desperately seeking environmental sustainability, besides these global UN-led initiatives, the last few years have also witnessed global level grassroots movements for climate and environmental action. The 'Fridays for Future' global climate strike movement started in 2018, when Greta Thunberg initiated school strikes for climate [12]. In the same year, the Extinction Rebellion global environmental movement began with about 100 academics signing a call to climate action, and continued with civil disobedient events [13]. Following these, some nations (Scotland being the first, 23 national governments have declared a climate emergency) and local governments (Darebin City Council, VIC, Australia being the first, 1990 local councils have declared a climate emergency) declared climate emergencies [14]. Most recently, during the 2021 United Nations climate change conference (COP26), 200 countries have been asked for their plans to cut emissions by 2030 [15].

Whilst the promising efforts at both fronts—i.e., UN and grassroot level initiatives—are putting increasing pressure on political leaders and fossil fuel companies, and rising awareness among the societies, the immediate gains have been so far limited [16]. Nonetheless, there are also other efforts to contribute to addressing global environmental challenges. Benefiting from digital data, technology and innovation is one of them [17–19].

Among the innovative technologies, artificial intelligence (AI) is considered as the most promising and prominent one [20]. AI is being applied in a wide spectrum of areas to address their central challenges in both public and private sectors [21,22]. These areas range from human resources to customer relationship, from law to security, from decision automation to education, from agriculture to mining, transportation to gaming, and many more [23–30].

AI is also being utilized in the environmental monitoring and protection and natural resource management areas [31,32]. Just to give some examples, AI is becoming an integral part of autonomous marine environmental monitoring [33], wildlife monitoring [34], environmental surveillance and flood protection [35], water quality modeling [36], biodiversity assessment [37], detecting natural disasters, damage, and incidents in the wild [38,39], and climate change modeling and preparedness [40].

This viewpoint advocates the need for appropriate technocentric instruments, in parallel to the ongoing policy and awareness efforts, for combatting climate change and its extreme weather events, and delivering SDGs. Against this backdrop, the remainder of this viewpoint focuses on elaborating the important role the Green AI approach could play in tackling global environmental sustainability challenges.

In recent years, the exponentially increasing technical capabilities and rapidly growing application areas have turned AI into one of the most popular technologies of our time [41]. AI, in a broad sense, is seen as "computational agents that act intelligently and perceive their environments in order to take actions that maximize chances of success" [42] (p. 148). AI, more specifically, is an umbrella term used for rules-based systems encompassing, but not limited to, machine and deep learning systems, neural networks, natural language processing, predictive analytics, computer vision, and robotics [43].

At present, there is a relatively clear understanding on AI's role in boosting the efficiencies at private companies and government agencies [44], as it has been experimented or adopted in pretty much in all industry sectors and in a wide spectrum of government services at varying levels [45]. When it gets to the role of AI in addressing global environmental sustainability problems (e.g., degradation of the natural environment and the climate crisis), there is much ambiguity. One of the leading reasons for this ambiguity has been the lack of or limited public (due to political short sightedness) and private (due to no or low profitably) sector interest in developing, adopting, and deploying AI for environmental sustainability—besides some small-scale demonstration projects and government initiatives [46]. However, in recent years we observe an increasing willingness and interest

in both public and private sectors. The main reasons for this involve adoption of new national policies, such as Green New Deal, and associated business growth potentials in AI for environmental sustainability [47].

In other words, while AI is at our service for improving efficiencies in businesses and government services, AI utilization for environmental sustainability seems to be, at least for now, at a degree of neglect [48]. Nonetheless, there exist, and some on the horizon, promising research and practical solutions of AI for environmental sustainability. Just to give some examples, AI is currently being utilized for assessing ecosystem services, detection and conservation of species, modeling climate change, natural disaster forecasting, waste and wastewater treatment, and so on so forth [49–51]. While the benefits of AI for environmental sustainability are evident from small-scale project initiatives and hypothetical or qualitative tests [52], these solutions have not been applied at scale in the real-world [53].

On the abovementioned point of the benefits of AI, for instance, the study by [54] (p. 2) scrutinized the role of AI in achieving SDGs and disclosed that "AI may act as an enabler on 134 targets (79%) across all SDGs, generally through a technological improvement, which may allow to overcome certain present limitations. However, 59 targets (35%, also across all SDGs) may experience a negative impact from the development of AI". Likewise, a study by [55] (p. 2), on whether AI enables environmental sustainability, revealed that "when SDGs related to society, economy, and environment were analyzed, it was observed that the environment category has the highest potential, with 93% of the targets being positively affected, whereas society has the largest negative effect with 38% of the targets exhibiting a negative interaction with AI".

The growing literature in the field also supports the abovementioned findings. For instance, a study by [56] (p. 283) disclosed that "AI can represent the vehicle to meet the SDGs allowing for the identification of the cultural change required by enterprises to achieve sustainability goals. Thus, business companies, academic research practitioners, and state policy should focus on the further development of the use of AI for sustainable development". Moreover, the authors of [57] underlined that the integration of AI into the SDGs initially happened through experimentation, and in most recent years through sustainable management and leadership programs. These programs concentrated on: (a) AI and the water crisis; (b) AI and the agriculture; (c) AI and sanitation and health.

Moreover, in [58] the authors warned us about the risks AI poses to the achievement of SDGs, with particular vulnerability for developing countries. Additionally, the authors of [59] revealed insights into public perception of linkages, synergies, and trade-offs between AI and SDGs. Likewise, according to [60] (p. 98), in support of SDG 14, "seas and oceans can be explored using submarine AI robots, such as Stanford's OceanOne. Marine resources can be monitored through AI-driven smart stationary and mobile sensors. Illegal fishing activities as well as marine life migration can be tracked through pattern recognition", and as for SDG 15, "AI can monitor different aspects of life on land, such as species health, land use changes, food security and nutrition, noise levels, weather-related stresses, and disease vectors and outbreaks. Predictive analytics can generate insights about population and desertification trends and the spread of epidemics".

In sum, numerous studies emphasized the critical importance of achieving foundational SDGs in reducing global risks [61], and many others discussed the role AI is playing and also could play in assisting the delivery of these goals by unlocking enormous sensing, data collection, analysis, prediction, and intervention capabilities [62]. Nevertheless, "given the fact that AI's internal decision-making process is non-transparent, some experts consider it to be a significant existential risk to humanity, while other scholars argue for maximizing the technology's exploitation" [60] (p. 95). This brings the importance of AI to be utilized for SDGs based on the principles of the technology being responsible, ethical, trustworthy, explainable, and also sustainable [63]. As elaborated by [64] "laissez-faire AI is a dangerous political choice".

The next section introduces the Green AI approach as an essential instrument for achieving global environmental sustainability.

Addressing the colossal environmental challenges call for a sustainable approach [65]. This approach also requires a new AI conceptualization and practice—i.e., Green AI—that involves a green-based technological perspective in the AI industry [66,67]. The green perspective includes "switching to an environmentally sustainable AI infrastructure, employing green sensing, watching for AI rebound effects, mandating AI transparency, accounting for the entire AI ecosystem, making non-energy policy a standard practice, integrating AI and climate policy, curbing the use of AI to extract fossil fuels, and addressing AI's impact on climate refugees" [68] (p. 1). In other words, as stated by [69] (p. 3) "green AI accommodates green sensing and moves away from short-term efficiency solutions to focus on a long-term ethical, responsible and sustainable practice that will help build sustainable urban futures for all".

This is to say, the Green AI approach moves away from short-term efficiency solutions to focus on a long-term ethical, responsible, and sustainable AI practice that will help build environmentally sustainable futures for all [70,71]. Making AI green, hence, requires adopting bias free, inclusive, trustworthy, explainable, ethical, and responsible principles to the AI technology that aims to alleviate the developmental challenges of the planet in a sustainable way [72,73]. This green approach, using AI to solve environmental sustainability challenges and using AI in a more sustainable way, can also serve as an enabler of smart and sustainable urban transformation or smart city development/transformation—as urbanization accounts for the majority of human activities that generate negative environmental externalities [74].

Growing technical capabilities and increasing application areas have turned AI into one of the most popular technologies of our time. Particularly, AI, when wisely harnessed for sustainability-inducing projects and applications, has the capacity to support SDGs [75]. Fortunately, at a time that we are desperately seeking environmental sustainability to not risk our existence on the planet [76], Green AI comes as a promising concept to adopt. In developing successful Green AI practices, the following AI for environmental sustainability principles are of significant importance [77] (pp. 8–9):

"(a) AI for environmental sustainability should be viewed from a multilevel view, as a multilevel view will help to build better models by capturing the complexity inherent in the real-world; (b) AI for environmental sustainability should be viewed from a system dynamics perspective, as a system dynamics perspective will capture interactions and feedback loops among the technology, users, and other stakeholders; (c) AI for environmental sustainability should be approached from a design thinking approach, as a design thinking approach will help to minimize potential unintended consequences and improve the effectiveness of AI solutions; (d) AI for environmental sustainability should incorporate environmental psychology and sociology perspectives, as understanding the psychological and sociological underpinnings of human response is necessary for effective long-term solutions, and; (e) AI for environmental sustainability should examine the economic value of AI for sustainability to develop our understanding of how AI differs from conventional information systems."

The successful Green AI practice also depends on effective government regulation and administration. Unfortunately, up until now there has been limited efforts to regulate AI [78,79]. The most notable effort is the European Commission's legal framework on AI that addresses the risks of AI [80]. However, there is no clear reference in the European Commission's regulation to the AI for environmental sustainability. Still, substantial work is needed to answer the following questions: what needs be done to develop Green AI at the policy level, how Green AI development can be supported by the administrations, what kind of mistakes should be avoided on the road to Green AI, how we can learn from best or good Green AI practices, and what types of legal liabilities should be considered. These questions form the basis of a new research agenda for scholars to investigate, and also practitioners and government officials get involved in the debates and discussions

in establishing a sound policy—in support of Green AI as an essential instrument for achieving global environmental sustainability.

In their paper [81] (p. 13), on the past, present, and future of AI, the authors stated that "nobody knows whether AI will allow us to enhance our own intelligence, as Raymond Kurzweil from Google thinks, or whether it will eventually lead us into World War III, a concern raised by Elon Musk. However, everyone agrees that it will result in unique ethical, legal, and philosophical challenges that will need to be addressed".

Developing and implementing the Green AI approach is one of these challenges that needs urgent attention; as the IPCC report [82] highlights, climate change is widespread, rapid, and intensifying, and our planet will reach temperature rise of about 1.5 °C in only around a decade.

Furthermore, most recently, as an outcome of COP26, the role that advanced digital technologies, such as AI, could play in addressing planetary challenges has been better comprehended by a number of countries; for example, Australian Government's new 'technology-led approach' to emissions reduction is one of the most prominent national climate change strategies in Australia [83]. While for politicians greenwashing [84] and technowashing [85] are, at times, applied methods to divert attention from the core issues, we hope for the sincerity of the current Australian Government administration, and others, for the use of technology for achieving sustainable outcomes and in a sustainable way [86]—as in the Green AI approach.

Against the above editorial commentary, the Special Issue on reviews and perspectives on smart and sustainable metropolitan and regional cities contributes to the efforts in improving research and practice in smart and sustainable metropolitan and regional cities and urbanism. The Special Issue brings together the key literature review and scholarly perspective pieces and forms an open access knowledge warehouse. It offers insights into research and practice in smart and sustainable metropolitan and regional cities by producing in-depth conceptual debates and perspectives, insights from the literature and best practice, and thoroughly identified research themes and development trends. The Special Issue, hence, serves as a repository of relevant information, material, and knowledge to support research, policymaking, practice, and transferability of experiences to address the challenges in establishing smart and sustainable metropolitan and regional cities and urbanism in the era of climate change, biodiversity collapse, natural disasters, pandemics, and socioeconomic inequalities.

The Special Issue includes the following 16 commentary, perspective, review, and research papers with the input of 58 urban scholars from Australia, Bangladesh, Brazil, China, Korea, Saudi Arabia, Spain, Spain, Sweden, Thailand, Turkey, the UK, and the US:

1. Greening the artificial intelligence for a sustainable planet: an editorial commentary.
2. The lived experience of residents in an emerging master-planned community [87].
3. Making the Gold Coast a smart city: an analysis [88].
4. Leveraging smart and sustainable development via international events: insights from Bento Gonçalves Knowledge Cities World Summit [89].
5. Sustainable smart cities and industrial ecosystem: structural and relational changes of the smart city industries in Korea [90].
6. Redesigning the municipal solid waste supply chain considering the classified collection and disposal: a case study of incinerable waste in Beijing [91].
7. Empowering a sustainable city using self-assessment of environmental performance on Ecocitopia platform [92].
8. Sustainability understanding and behaviors across urban areas: a case study on Istanbul city [93].
9. Overview and exploitation of haptic tele-weight device in virtual shopping stores [94].
10. Framing corporate social responsibility to achieve sustainability in urban industrialization: case of Bangladesh ready-made garments [95].
11. Data-driven analysis on inter-city commuting decisions in Germany [96].

12. Exploring the role of digital infrastructure asset management tools for resilient linear infrastructure outcomes in cities and towns: a systematic literature review [97].
13. Blockchain and building information management (BIM) for sustainable building development within the context of smart cities [98].
14. Green artificial intelligence: towards an efficient, sustainable and equitable technology for smart cities and futures [99] (Yigitcanlar et al., 2021).
15. Towards Australian regional turnaround: insights into sustainably accommodating post-pandemic urban growth in regional towns and cities [100].
16. Social capital and sustainable social development: how are changes in neighborhood social capital associated with neighborhood sociodemographic and socioeconomic characteristics? [101].

This collection of papers focused on answering the overall questions of this Special Issue—namely, what the critical aspects of smart and sustainable metropolitan and regional cities are, and how we can construct such cities that are resilient to the increasing severity and frequency of climate change effects, biodiversity loss, natural disasters, and pandemics, and are the generators of socioeconomic equalities, and are the vehicles of delivering SDGs for a sustainable planet.

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