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THE DIGITAL ECONOMY AND THE GREEN ECONOMY: COMPATIBLE AGENDAS?

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Abstract

The governance ecosystem of the 21st century is characterized by an accelerating rate of technological change. The velocity and scope of this change will likely continue to increase. In the past decade, the digital economy and the green economy have become important topics for governments' policy agendas. While a significant attention has been given to the promises and perils of the digital economy, little attention has been given to the compatibility of both agendas. This begs the question: Is the digital economy compatible with the green economy? Although efforts are being made to find synergies between the two agendas, the pace of action on the green economy has been generally slow compared to the exponential acceleration in the digital economy. This paper explores the environmental impacts of the digital economy (rare earth extraction, coal-driven energy for the cloud, carbon footprints from data centres, artificial intelligence models and bitcoins). It argues that without urgent system-wide actions from governments, it will be impossible for the two agendas to become compatible.

Key words. Digital Economy. Green economy. Compatibility. Governance Ecosystem. 21st century.

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INTRODUCTION

The governance ecosystem of the 21st century is characterized by an accelerating rate of technological change. The velocity and scope of this change will likely continue to increase. As futurist and inventor, Ray Kurzweil, observed at the turn of the 21st century: "We won't experience 100 years of progress in the 21st century — it will be more like 20,000 years of progress (at today's rate)," (Kurzweil, 2001: para 1)[1] Kurzweil argued that contrary to the conventional view of technological change as "intuitive linear", an analysis of the history of technology demonstrates that technological change is exponential. Exponential technological change includes the integration of "biological and nonbiological intelligence, immortal software-based humans, and ultra-high levels of intelligence" (Kurzweil, 2001: para 1). The author argues that, "machine intelligence will surpass human intelligence, leading to the Singularity — technological change so rapid and profound it represents a rupture in the fabric of human history" (Kurzweil, 2004: 381).[2] As the Head of the Stanford Artificial Intelligence Laboratory in California, Fei-Fei Li, puts it, "We live in a mind-blowingly different world than our grandparents" (cited in Butler, 2016).[3]

The governance ecosystem today is "a different world from the one faced by prior generations of public sector leaders and decision-makers" (Bourgon, 2017:41)[4]. In both policy and academic circles, it has become common knowledge that a fourth industrial revolution is underway, which represents the emergence of a digital economy (sometimes called the 'new economy' or 'internet economy'). It signals a fundamental transformation of modern societies and economies, driven largely by exponential technological change. The fourth revolution involves integrating the physical, digital and biological worlds, which contributes to semi-automated decision-making processes and highly interconnected production chains (Schwab 2016)[5]. Schwab (2016:11) explained that the first industrial revolution (from approximately 1760 to 1840) was triggered by construction of railroads and the invention of the steam engine. The second industrial revolution (late 19th century to the early 20th century) was fostered by the advent of electricity and the assembly line. Both inventions provided the impetus for mass production. The third industrial revolution began in the 1960s. This is generally called the computer or digital revolution because it was catalysed by the development of semiconductors, mainframe computing (1960s), personal computing (1970s and 80s) and the internet (1990s). The fourth industrial revolution began at the turn of the 21st century and it builds on the digital revolution: "it is characterized by a much more ubiquitous and mobile internet, by smaller and more powerful sensors that have become cheaper, and by artificial intelligence and machine learning." For Brynjolfsson and McAfee (2014),[6] our

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[1] Kurzweil, Ray. 2001. "The Law of Accelerating Returns." March 7, 2001. https://www.kurzweilai.net/the-law-of-accelerating-returns or see Kurzweil R. (2004) The Law of Accelerating Returns. In: Teuscher C. (eds) Alan Turing: Life and Legacy of a Great Thinker. Springer, Berlin, Heidelberg

[2] Kurzweil R. (2004) The Law of Accelerating Returns. In: Teuscher C. (eds) Alan Turing: Life and Legacy of a Great Thinker. Springer, Berlin, Heidelberg

[3] Butler, Declan. 2016. "A World Where Everyone Has a Robot: Why 2040 Could Blow Your Mind." Nature News 530 (7591): 398. https://doi.org/10.1038/530398a.

[4] Bourgon, Jocelyne. 2017. "The New Synthesis of Public Administration Fieldbook". Copenhagen, Dansk Psykologisk Forlag A/S.

[5] Schwab, K. 2016. The Fourth Industrial Revolution. Geneva: World Economic Forum.

[6] Brynjolfsson, E. and A. McAfee. 2014. The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies. New York: W. W. Norton & Company.

current digital era is a “second machine age.” The first machine age — a period since the first industrial revolution — saw the automation of tasks that had relied on manual labour. The second machine age involved the automation of cognitive tasks and cheap production at a large scale.

While significant attention has been given to the promises and perils of the digital economy (e.g., see Tapscott 1994)[7], little attention has been given to nexus between the digital economy and the green economy agenda. Within the policy, academic and management circles, the discourse tends to focus largely on productivity, efficiency gains, value creation and inclusive growth. Relying on data as its fuel (Accenture, 2016),[8] the digital economy has become a powerful catalyst for sharing information, boosting inclusive growth and spreading transformative ideas in a world that is more interconnected and globalized than ever before.

The phrase ‘data is the new oil’[9] has become part and parcel of the discussion on artificial intelligence (AI), especially deep learning.[10] For large private entities, there has been a major turn to the financial value of big data. The world’s leading technology giants are now at the forefront of commodifying data. Referred to as the ‘Frightful Five’, Google, Facebook, Microsoft, Apple, and Amazon, largely shape our experience with the internet and digital technologies including AI (Nemitz, 2018).[11] Even so, the current digital economy discussions tend to overlook the potential impact of the digital carbon footprint.

This paper raises the question: Is the digital economy compatible with the green economy agenda? What actions are needed to ensure the compatibility of both agendas? The paper explores this question by first providing an overview of the digital economy and its environmental impact. More specifically, it focuses on rare earth extraction, coal-driven energy for the cloud, and digital ecosystems and their impact on the environment (data centres, AI models and bitcoins). Next, this paper examines the concept of sustainable development and the green economy agenda in the context of the 2030 Agenda for Sustainable Development. Following this, the paper discusses whether the digital economy and green economy are compatible agendas. Lastly, the paper offers some concluding remarks.

Digital Economy, Rare Earth Extraction and Carbon Footprint

Digital Economy and Systemic Risks

Atkinson and McKay (2007: para 1 and 3)[12] note that, “for most people the digital economy

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[7] Tapscott, Don (1994). The digital economy: promise and peril in the age of networked intelligence. New York: McGraw-Hill

[8] Accenture. 2016. Data: The Fuel of the Digital Economy and SME Growth https://www.accenture.com/_acnmedia/pdf-29/accenture-data-the-fuel-of-the-digital-economy-and-sme-growth.pdf

[9] See Pringle, Ramona. 2017. “‘Data Is the New Oil’: Your Personal Information Is Now the World’s Most Valuable Commodity | CBC News.” CBC. August 25, 2017. https://www.cbc.ca/news/technology/data-is-the-new-oil-1.4259677.

[10] Note that big datasets are vital for neural networks’ learning processes.

[11] Nemitz, Paul. 2018a. “Constitutional Democracy and Technology in the Age of Artificial Intelligence.” Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 376 (2133)

refers to the economy conducted on the Internet, but the digital economy is much broader than this. The digital economy represents the pervasive use of IT (hardware, software, applications and telecommunications) in all aspects of the economy, including internal operations of organizations (business, government and non-profit); transactions between organizations; and transactions between individuals, acting both as consumers and citizens...The technologies underlying the digital economy also go far beyond the Internet and personal computers. IT is embedded in a vast array of products, and not just technology products like cell phones, GPS units, PDAs, MP3 players, and digital cameras." The digital economy, intertwined with the traditional economy, entails "economic activity that results from billions of everyday online connections among people, businesses, devices, data, and processes. The backbone of the digital economy is hyperconnectivity which means growing interconnectedness of people, organisations, and machines that results from the Internet, mobile technology and the internet of things (IoT)."[13] For Mesenbourg (2001),[14] there are three primary components of the digital economy: e-business infrastructure (hardware, software, telecoms, networks, human capital, etc.); e-business (how business is conducted, any process that an organization conducts over computer-mediated networks); and e-commerce (transfer of goods, for example when a book is sold online).

The digital revolution is in its full swing (Helbing et. al 2017).[15] It is a result of the coming together of multiple related technologies and emerging factors, including biotechnology, robotics, and nanotechnology each of which are rapidly changing the world (OECD, 2003[16]). It is being "fuelled by the exponential growth in computing power, storage capacity, networking and interoperability that gather and process massive amounts of data at a previously unknown speed." (Bourgon, 2017:34). The amount of data that is often produced in the digital economy continues to grow exponentially: "From the dawn of civilization to 2003, Google calculates humans produced five exabytes of data. We now generate 2.5 exabytes of data [that is 2.5 billion gigabytes (GB)] every single day, and [International Data Corporation] IDC estimates that the amount of data will double every two years to 2020. Data is diverse, created by the billions of people using social networks or digital cameras, by businesses connecting employees, suppliers and customers through their digital platforms, and by the millions of sensors, connected objects and communication" (Accenture, 2016:2). IDC now predicts that the "collective sum of the world's data will grow from 33 zettabytes this year to a 175ZB by 2025, for a compounded annual growth rate of 61 percent"[17]. The datasphere has three

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[12] Atkinson, Robert, and Andrew McKay. 2007. "What Is the Digital Economy?" 2007. https://www.govtech.com/dc/articles/What-Is-the-Digital-Economy.html.

[13] Deloitte. n.d. "What Is Digital Economy? Unicorns, Transformation and the Internet of Things." Deloitte Malta. Accessed August 20, 2019. https://www2.deloitte.com/mt/en/pages/technology/articles/mt-what-is-digital-economy.html.

[14] Mesenbourg, T.L. (2001). "Measuring the Digital Economy". U.S. Bureau of the Census. https://www.census.gov/content/dam/Census/library/working-papers/2001/econ/umdigital.pdf

[15] Helbing, Dirk, Bruno S. Frey, Gerd Gigerenzer, and Ernst Hafen. 2017. "Will Democracy Survive Big Data and Artificial Intelligence?" Scientific American Online (February).

[16] Organisation for Economic Co-operation and Development (OECD). 2003. Emerging Systemic Risks in the 21st Century: An Agenda for Action. Paris: OECD.

[17] Patrizio, Andy. 2018. "IDC: Expect 175 Zettabytes of Data Worldwide by 2025." Network World. December 3, 2018. https://www.networkworld.com/article/3325397/idc-expect-175-zettabytes-of-data-worldwide-by-2025.html.

locations. First is the core, which includes traditional and cloud data centers; second is the edge, which includes things like cell towers and branch offices; and the third is endpoints, which include PCs, smartphones, and the Internet of Things (IoT) devices.

While the digital economy presents numerous opportunities, it is also generating socio-economic risks on a large scale: "It is unleashing deep emotions: excitement for some about the unprecedented potential, fear for others about the capacity to absorb the dislocation associated with this transformation, and even anger for those who are losing hope that they may benefit from the new emerging economy in spite of their best efforts" (Bourgon, 2017:34). The digital era is characterized by complex interdependence (Keohane and Nye, 1977[18]). The key implication of this complex interdependence is that emerging systemic risks and threats can spread faster than ever before (OECD, 2003).

According to Helbing and colleagues (2017)[19], we are in the middle of a technological upheaval that will transform the way society is organized. This means that we must make the right decisions *now*. The authors noted that:

> "The amount of data we produce doubles every year. In other words: in 2016 we produced as much data as in the entire history of humankind through 2015. Every minute we produce hundreds of thousands of Google searches and Facebook posts. These contain information that reveals how we think and feel. Soon, the things around us, possibly even our clothing, also will be connected with the Internet. It is estimated that in 10 years' time there will be 150 billion networked measuring sensors, 20 times more than people on Earth. Then, the amount of data will double every 12 hours. Many companies are already trying to turn this Big Data into Big Money. ... One thing is clear: the way in which we organize the economy and society will change fundamentally. We are experiencing the largest transformation since the end of the Second World War; after the automation of production and the creation of self-driving cars the automation of society is next. With this, society is at a crossroads, which promises great opportunities, but also considerable risks. If we take the wrong decisions it could threaten our greatest historical achievements."

These trends show that we live in the age of data, with varying implications for society at large, including the environment. There is a need to reflect on digital ecosystems and their carbon footprints. Let's begin by addressing rare earth extraction and coal.

Rare Earth Extraction (REE) and Coal

i.Rare Earth Extraction

In the book, The Elements of Power: Gadgets, Guns, and the Struggle for a Sustainable Future in the Rare Metal Age, Abraham (2017)[20], examined how rare earth elements are the backbone of modern digital technologies such as tablets, smartphones, desktop computers, etc. They are crucial for technology giants like

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[18] Keohane, Robert & Nye, Joseph. 1977. Power and Interdependence: World Politics in Transition. Boston: Little, Brown.

[19] Hellbing et al. 2017. https://www.scientificamerican.com/article/will-democracy-survive-big-data-and-artificial-intelligence/

[20] Abraham, David S. 2017. The Elements of Power: Gadgets, Guns, and the Struggle for a Sustainable Future in the Rare Metal Age. Reprint edition. Yale University Press.

Apple, but little attention has been paid to their environmental impacts, especially in developing countries where these materials are extracted. Abraham (2017) contends that we have entered a new era, the rare metal era — the products we use every day, from smartphones to cars, require a great number of rare metals, combined in increasingly complicated amalgamations. The author observed that although rare metals are critical for the development of green technologies and that they increasingly confer economic and geopolitical advantages for countries that largely control their export (China in this case), these metals are understudied. Xiaoyue and Graedel (2011)[21] state that "China's export restriction of REE raw materials has created a perfect storm in which the mining monopoly of China, rapid increases in global REE demand, and Chinese promotion of domestic downstream processing industries come together to make a reliable REE supply to the global market uncertain."

China is by far the world's largest producer of rare earths today and accounts for about 70% of global production (Makortoff, 2019).[22] Natural Resources Canada (2019) highlighted that in 1987, China's production of rare earth was estimated at 5,000 tonnes while the rest of the world had an estimated production of 35,000 tonnes. "By 2005, China's production was estimated to have reached 135,000 tonnes, while the rest of the world produced 3,000 tonnes. In 2017, China produced an estimated 117,000 tonnes, while the rest of the world produced an estimated 18,000 tonnes."[23] The graph below, ***fig. 1***, shows REEs production by China compared with the rest of the world in the last three decades.

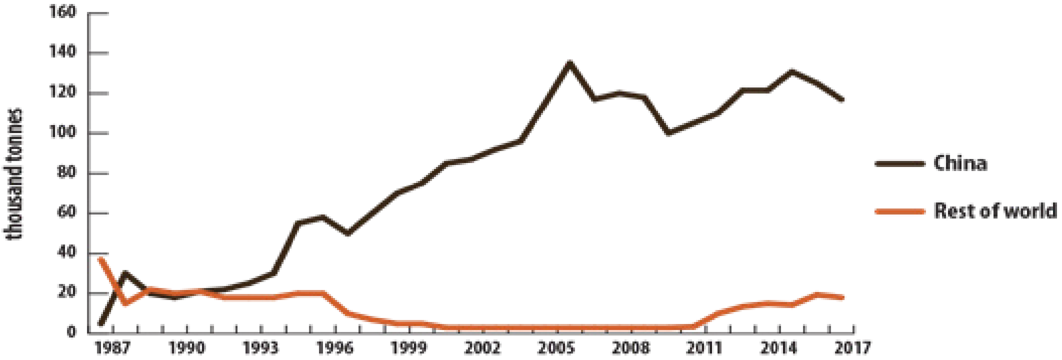

Fig. 1. Source: Natural Resources Canada. 2019. World REEs supply, 1987-2017 (p)

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[21] Du, Xiaoyue, and T. E. Graedel. 2011. "Uncovering the Global Life Cycles of the Rare Earth Elements." Scientific Reports 1 (November). https://doi.org/10.1038/srep00145.

[22] Makortoff, Kalyeena. 2019. "US-China Trade: What Are Rare-Earth Metals and What's the Dispute?" The Guardian, May 29, 2019, sec. Business. https://www.theguardian.com/business/2019/may/29/us-china-trade-what-are-rare-earth-metals-and-whats-the-dispute.

[23] Natural Resources Canada. 2019. Rare earth elements facts. https://www.nrcan.gc.ca/rare-earth-elements-facts/20522

Although there have been recent talks about China's positive efforts towards a 'green economy' (e.g. World Economic Forum's article, 'Here is how China is Going Green'),[24] the 2018 Environmental Performance Index (EPI) ranked China as 120th out of 180 countries.[25] Large scale REE production in China has raised grave environmental concerns, particularly with regard to heavy metal and radioactive emissions in groundwater, rivers, soil, plants, and the atmosphere around mine sites (Liang et. al, 2014).[26]

Abraham (2017:31) stated that, "as demand for these rare metals grows, it is important to understand the environmental and geopolitical effects of increased production. Whereas the total environmental impact of producing rare metals is small in comparison to producing traditional commodities, the impact per kilogram (or pound) is far greater because of the quantity of chemicals and energy needed to refine the metals. And with little oversight of operations in some countries, the production of rare metals can be ruinous to the surrounding communities."

Abraham further asserts that the environmental footprint — that is, the amount of waste from rare earth operations — is staggering. For example, only 0.2 percent of mined clay contains rare earth elements. This means that 99.8 percent is discarded waste (called "tailings") that is dumped back into the hills and streams, with significant environmental consequences. In short, every step in the life cycle of modern gadgets — production, use, and disposal — produces green house gases.

Makortoff (2019) also explains that rare earth metals are often low in concentration and they are difficult and expensive to mine. The process damages the environment, with ecosystems put at risk by pit mining, the release of metal by-products from refineries, and water contamination from particles being dumped during waste disposal. Navarro and Zhao (2014[27]) elaborate on the negative environmental impacts of REE. According to the authors, REEs gain increasing importance in many new energy technologies and systems that contribute to reduce greenhouse gas emissions and fossil fuel depletion (e.g., wind turbine, electric vehicles, high efficiency lighting, batteries, and hydrogen storage) due to their unique physical and chemical properties. "However, it is well known that production of REEs is far from environmentally sustainable as it requires significant material and energy consumption while generating large amounts of air/water emissions and solid waste" (Navarro and Zhao, 2014, emphasis added). In many REE operations, there are large tailings ponds with wastes from the various extraction processes. The mixture of wastewater, chemicals used for processing, and ground-up materials (including heavy metals) carry significant environmental costs. These wastes often include radioactive elements such as thorium (Th) and uranium (Navarro and Zhao, 2014). Today, in large part due to the Bayan Obo

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[24] World Economic Forum. 2019. 'Here is How China is Going Green' https://www.weforum.org/agenda/2018/04/china-is-going-green-here-s-how/

[25] Yale Center for Environmental Law & Policy, Yale University Center for International Earth Science Information Network, World Economic Forum. 2018. https://epi.envirocenter.yale.edu/downloads/epi2018policymakerssummaryv01.pdf

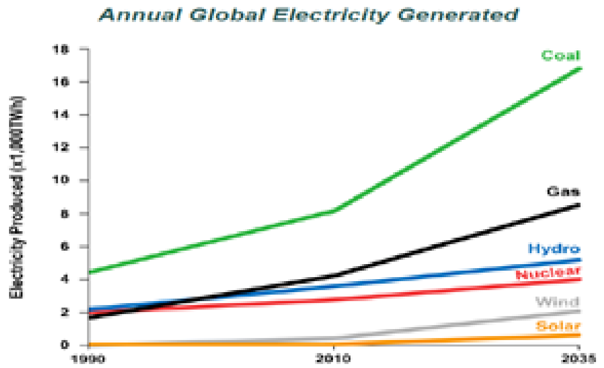
[26] Liang, T., Li, K., and Wang, L. (2014). State of rare earth elements in different environmental components in mining areas of China. Environ. Monit. Assess. 186, 1499–1513

[27] Navarro, Julio, and Fu Zhao. 2014. "Life-Cycle Assessment of the Production of Rare-Earth Elements for Energy Applications: A Review." Frontiers in Energy Research 2. https://doi.org/10.3389/fenrg.2014.00045.

mine in Inner Mongolia, China maintains its position as the largest source of REEs in the world, and accounts for 83.7% of Chinese reserves. Several analysts have highlighted negative environmental damages associated with this mine: “Crops and animals have died around a crusty lake of radioactive black sludge formed from mining waste near a major mining site in Baotou, Inner Mongolia. It’s so large that it is visible by satellite”. [28] Overall, the production of REEs involves a large number of process steps, out of which many incur significant material/energy consumption and environmental release (Golev et al., 2014). [29] This calls for framing issues relating to the REE, digital economy, and green economy from a broad perspective.

ii. Coal

Digital traffic requires enormous distributed physical infrastructure of equipment that specifically and almost exclusively consumes electricity. Considering that coal is the world’s largest and fastest growing source of electricity, Mills (2013)[30] argues that the digital universe and cloud begins with coal (see ***fig. 2)***. To Mills, the “Cloud is a Global Network of Interconnected Always-On Electricity-Consuming Devices” (2013:15).



Data Source: IEA

Coal is 40% of global electricity and is forecast, by the IEA, to supply 50% of the growth in world demand over the next 20 years.

Fig. 2. Source: Mills (2013). *The Cloud Begins With Coal: Big Data, Big Networks, Big Infrastructure and Big Power: An Overview of Electricity Used by the Global Digital Ecosystem*

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[28] Los Angeles Times. 2019. “The Hidden Costs of China’s Rare-Earth Trade.” Los Angeles Times. July 29, 2019. https://www.latimes.com/world-nation/story/2019-07-28/china-rare-earth-tech-pollution-supply-chain-trade.

[29] Golev,A., Scott, M., Erskine, P. D.,Ali, S. H., and Ballantyne, G. R. (2014). Rare earths supply chains: current status, constraints and opportunities. Resour. Policy 41, 52-59.

[30] Mills, Park. 2013. The Cloud Begins With Coal: Big Data, Big Networks, Big Infrastructure and Big Power: An Overview of Electricity Used by the Global Digital Ecosystem. https://www.tech-pundit.com/wp-content/uploads/2013/07/Cloud_Begins_With_Coal.pdf

In the next two decades, demand for energy from coal will continue to increase, but each stage of the life cycle of coal — extraction, transport, processing, and combustion — generates huge wastes and contributes negatively to the environment (Epstein et. al, 2011).[31] Epstein and colleagues (2011:73) noted that "in 2005, coal-derived electricity was responsible for 7.856 Gt of CO2 emissions or 30% of all worldwide carbon dioxide (CO2) emissions, and 72% of CO2 emissions from power generation (one gigaton = one billion tons; one metric ton=2,204 pounds). Non–power-generation uses of coal, including industry (e.g., steel, glass-blowing), transport, residential services, and agriculture, were responsible for another 3.124 Gt of CO2, bringing coal's total burden of CO2 emissions to 41% of worldwide CO2 emissions in 2005." Epstein and colleagues (2011) estimated that the waste stream generated from coal are costing the U.S. public a third to over one-half of a trillion dollars annually. Many of these, so-called 'externalities,' are cumulative. The authors, using the U.S. as an example, explain the negative environmental impacts of coal as follows:

> "In the United States in 2005, coal produced 50% of the nation's electricity but 81% of the CO2 emissions. For 2030, coal is projected to produce 53% of U.S. power and 85% of the U.S. CO2 emissions from electricity generation. None of these figures includes the additional life cycle greenhouse gas (GHG) emissions from coal, including methane from coal mines, emissions from coal transport, other GHG emissions (e.g., particulates or black carbon), and carbon and nitrous oxide (N2O) emissions from land transformation in the case of MTR coal mining. Coal mining and combustion releases many more chemicals than those responsible for climate forcing. Coal also contains mercury, lead, cadmium, arsenic, manganese, beryllium, chromium, and other toxic, and carcinogenic substances. Coal crushing, processing, and washing releases tons of particulate matter and chemicals on an annual basis and contaminates water, harming community public health and ecological systems. Coal combustion also results in emissions of NOx, sulfur dioxide (SO2), and mercury; all of which negatively affect air quality and the environment at large." (Epstein et. al, 2011:74).

Despite the negative environmental footprint of coal, it continues to dominate the global energy arena due to its abundance, affordability and wide distribution across the world.[32] Today, the top ten leading producers of coal include the large economies of China, U.S., Australia, India, Indonesia, Russia, South Africa, Germany, Poland and Kazakhstan. Dillinger (2009) notes that "China is the chief coal producer while the United States comes in second. Other major coal producers are India and Australia. Five countries, namely China, the United States, Russia, India and Japan accounted for over 75% of worldwide coal consumption. Despite the swift deployment of renewable energy, mainly in the background of debates around climate change, it is coal that is responsible for the largest upsurge in energy requirement of all energy sources. Approximately 90% of the total global coal is produced by ten countries with China running in the lead."

For Keisuke Sadamori, the International Energy Agency's (IEA)'s Director for En-

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[31] Paul R. Epstein, Jonathan J. Buonocore, Kevin Eckerle, Michael Hendryx, Benjamin M. Stout III, Richard Heinberg, Richard W. Clapp, Beverly May, Nancy L. Reinhart, Melissa M. Ahern, Samir K. Doshi, and Leslie Glustrom. 2011. Full cost accounting for the life cycle of coal in "Ecological Economics Reviews." Robert Costanza, Karin Limburg & Ida Kubiszewski, Eds. Ann. N.Y. Acad. Sci. 1219: 73–98.

[32] Ibid.

ergy Markets and Security: "The story of coal is a tale of two worlds with climate action policies and economic forces leading to closing coal power plants in some countries, while coal continues to play a part in securing access to affordable energy in others. "For many countries, particularly in South and Southeast Asia, it is looked upon to provide energy security and underpin economic development." (World Economic Forum, 2019).[33] The reality is that while many European countries like Sweden, France and Denmark are taking measures to accelerate their transition to renewables, it's a different story in much of Eastern Europe, with new coal-fired plants being constructed in Poland, Greece and the Balkan states. In fact, "the divide between countries phasing out coal and those seeing increasing demand for it makes agreeing on global controls on fossil-fuel power generation and emissions levels difficult" (World Economic Forum, 2019).

Digital Ecosystem, Energy and Carbon Footprint: Data Centres, AI Models & Bitcoins

i. Data Centres

The global digital ecosystem consumes a significant amount of energy that contributs to CO2 emissions. Hodgson (2015)[34] notes that "overall carbon emissions from the digital ecosystem is significant." According to the author, "global data centres are estimated to equate to 2% of global emissions equal to the emissions from global aviation". And with only a quarter of the world population online and our thirst for "expecting anything, anytime, anywhere" will place greater pressure on our physical infrastructure and planet. For example, Andrew Ellis, professor of Optical Communications at Aston University stated that "8% of UK energy generation is used by the internet and it could consume all UK power by 2035."

Mills (2013:9) notes that progress in data center equipment efficiency will continue, "but forecasts still show substantial growth in data center energy, and in some estimates comprise the fastest growing part of the ICT energy-using ecosystem in the next decade. … Data centers have entered a new era in terms of the character of traffic. Most data-center traffic until recently was associated with managing data flowing to and from users. Intra-data-centre traffic is now growing far faster than traffic to and from end users due to the rising use of IT services, remote storage, and the increasing use of real-time processing (enabled by high speed user connectivity) such as mapping, voice recognition, industrial and medical diagnostics, and big data analytics."

A $15 billion annual industry, forecasted to triple to $45 billion in five years, data centres rely heavily on energy. They usually run 24/7 all year round. Their high energy consumption can be "attributed primarily to [...] IT demands and cooling equipment, as well as lighting, power distribution and other requirements. The cooling system alone may account for up

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[33] World Economic Forum. 2019. "These Countries Are Driving Global Demand for Coal." World Economic Forum. 2019. https://www.weforum.org/agenda/2019/02/these-countries-are-driving-global-demand-for-coal/.

[34] Hodgson, Christopher. 2015. "Can the Digital Revolution Be Environmentally Sustainable?" The Guardian, November 13, 2015, sec. Global. https://www.theguardian.com/global/blog/2015/nov/13/digital-revolution-environmental-sustainable.

to 40% in average of the energy demands of a data centre, with the most efficient systems using 24% of the total energy and the least efficient 61%."(Avgerinou et. al, 2017:1-2)[35].

Mills (2013:36) also observed from a global survey that energy cost and availability is the number one worry for data centre operators: "A typical data center costs roughly $7 million per megawatt to build, and another $9 million per megawatt for the cost of electricity over the facility's ten year operating life, assuming low-cost power. Thus, for example, a single 50 MW enterprise data center sited in Iowa (70% coal, 25% wind) instead of higher cost California (no coal), saves $350 million in electricity expenses over the life of that single data center." On average, a server room at a data center can use enough electricity to power 180,000 homes (Walsh, 2013).[36]

In a 2018 report by Super Micro Computer, titled Data Centers and the Environment[37], it was noted that data centres account for 3% of the global electricity supply and consume more power than the entire UK. Electronic waste (E-waste), which is a by-product of activities from data centres, account for 2% of solid waste and 70% of toxic waste. The report, based on a survey conducted to understand what businesses are doing to measure and address the environmental impacts of their data centers, noted that 43% of organizations do not have an environmental policy, and 58% of the respondents did not know their data center's Power Usage Effectiveness (PUE) — that is, the ratio of total energy used by a data center facility to the energy delivered to the IT equipment. When it came to the execution of the actual data center design, 59% of respondents considered power efficiency as "extremely important" or "important," outranked by technology considerations in ease of maintenance (74%) and extended product lifecycle (65%). Footprint reduction was considered as the least important (see ***fig.3*** below).

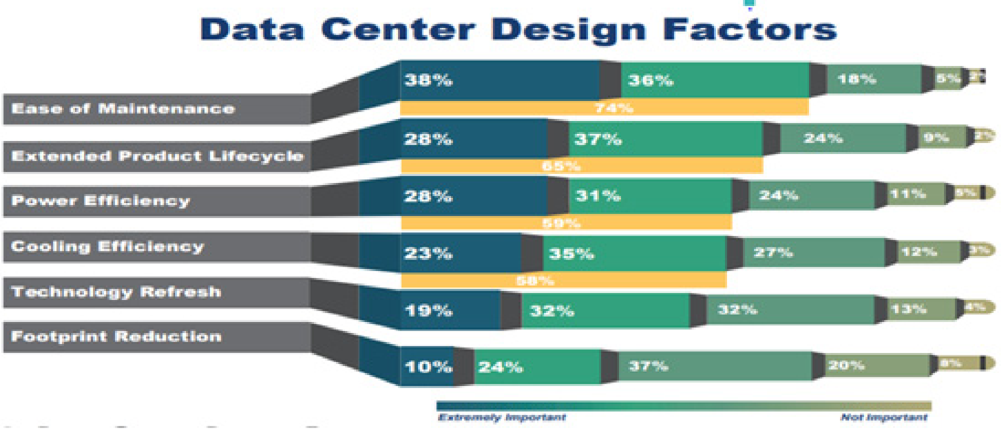

Fig.3 – Super Micro Computer, 2013

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[35] Avgerinou, Maria, Paolo Bertoldi, and Luca Castellazzi. 2017. "Trends in Data Centre Energy Consumption under the European Code of Conduct for Data Centre Energy Efficiency." Energies 10 (10): 1470.

[36] Walsh, Bryan. 2013. "The Surprisingly Large Energy Footprint of the Digital Economy [UPDATE]." Time. Accessed August 21, 2019. http://science.time.com/2013/08/14/power-drain-the-digital-cloud-is-using-more-energy-than-you-think/.

[37] Super Micro Computer (2018). Data Centers and the Environment. https://www.supermicro.com/wekeepitgreen/Data_Centers_and_the_Environment_Dec2018_Final.pdf

The ptinciple reasons for not having an environmental policy are high costs (29%) and lack of resources or understanding (27%), while 14% simply don't consider environmental issues a priority (Super Micro Computer, 2013).

Hodgson (2015) also reflects on four key challenges to building a digital revolution that is sustainable. These challenges include:

1. ***"Lack of awareness*** – there is little understanding publicly that digital action has an environmental impact. All digital actions are perceived to be positive for the environment and outsourcing hardware to the cloud further breaks our link with nature.
2. ***Lack of controllable levers*** – digital actions that drive environmental impacts are typically small and dispersed across many people and organisations and there is very little systems thinking on digital environmental impacts. Digital suppliers are not overly cooperative.
3. ***Pace of change*** – due to the speed of change of the digital ecosystem once you have identified your impacts the system or the product itself changes and your findings become less meaningful.
4. ***Lack of assessment tools*** – current environmental assessment methods of digital [footprints] are not good enough because they cannot dynamically assess the impacts. The pace of change means it is very difficult to have a constant baseline to compare performance against."

(Hodgson, 2015)

ii. AI Models

In a recent ground-breaking paper, Strubell and colleagues (2019)[38] contended that "progress in hardware and methodology for training neural networks has ushered in a new generation of large networks trained on abundant data. These models have obtained notable gains in accuracy across many NPL [Natural language processing] tasks. However, these accuracy improvements depend on the availability of exceptionally large computational resources that necessitate similarly substantial energy consumption. As a result, these models are costly to train and develop, both financially, due to the cost of hardware and electricity or cloud compute time, and environmentally, due to the carbon footprint required to fuel modern tensor processing hardware." In this paper, the authors quantified the approximate financial and environmental costs of training a variety of recently successful neural network models for Natural language processing (NLP). The authors found that the process for training a single large AI model can emit more than 626,000 pounds of carbon dioxide equivalent – nearly five times the lifetime emissions of the average American car (and that includes manufacturing cost).[39] In other words, training a single AI model can emit as much carbon as five cars do over their

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[38] Strubell, Emma, Ananya Ganesh, and Andrew McCallum. 2019. "Energy and Policy Considerations for Deep Learning in NLP." ArXiv:1906.02243 [Cs], June. http://arxiv.org/abs/1906.02243.

[39] Hao, Karen. 2019. "Training a Single AI Model Can Emit as Much Carbon as Five Cars in Their Lifetimes." MIT Technology Review. Accessed August 14, 2019. https://www.technologyreview.com/s/613630/training-a-single-ai-model-can-emit-as-much-carbon-as-five-cars-in-their-lifetimes/

lifetimes. The authors found that "the computational and environmental costs of training grew proportionally to model size and then exploded when additional tuning steps were used to increase the model's final accuracy. In particular, they found that a tuning process known as neural architecture search, which tries to optimize a model by incrementally tweaking a neural network's design through exhaustive trial and error, had extraordinarily high associated costs for little performance benefit. Without it, the most costly model, BERT, had a carbon footprint of roughly 1,400 pounds of carbon dioxide equivalent, close to a round-trip trans-America flight for one person" (Hao, 2019). The results of this work show that there is a growing problem with AI's digital footprint and that AI research is increasingly being privatized, contributing to inequitable access to research. The sheer intensity of resources required to produce worthy results has made it increasingly challenging for people working in academia to contribute to AI research.

A recent report[40] by Greenpeace and the North China Electric Power University revealed that "China's data centers produced 99 million metric tons of carbon dioxide last year, the equivalent of about 21 million cars on the road [...] Data centers store electronic information like emails, photos and videos, and worldwide they consume between 3% and 5% of total global electricity, and rival the airline industry in terms of carbon emissions. ... China is outpacing the US in renewable energy, and has made huge progress in developing solar projects. In 2017, it set a goal for clean energy to meet 20% of its energy needs by 2030. However, despite this vast capacity for green power, most Chinese data centers don't use it."

iii. Bitcoins and Energy Consumption

Another key area of concern when it comes to energy consumption and digital carbon footprint is the mining of bitcoins. Truby (2018:399)[41] argues that:

> "The vast transactional, trust and security advantages of Bitcoin are dwarfed by the intentionally resource-intensive design in its transaction verification process which now threatens the climate we depend upon for survival. Indeed Bitcoin mining and transactions are an application of Blockchain technology employing an inefficient use of scarce energy resources for a financial activity at a point in human development where world governments are scrambling to reduce energy consumption through their Paris Agreement climate change commitments and beyond to mitigate future climate change implications. Without encouraging more sustainable development of the potential applications of Blockchain technologies which can have significant social and economic benefits, their resource-intensive design combined now pose a serious threat to the global commitment to mitigate greenhouse gas emissions."

Some bankers and renowned economists have said that cryptocurrency is unstable in price and useless in most real-world transactions, but its effects "will not go away anytime soon". [42] Its reliance on speculation drives prices up and down,

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[40] "China's Data Centers Produce as Much Carbon Emissions as 21 Million Cars - CNN." n.d. Accessed September 12, 2019. https://www.cnn.com/2019/09/10/asia/china-data-center-carbon-emissions-intl-hnk/index.html.

[41] Truby, Jon. 2018. "Decarbonizing Bitcoin: Law and Policy Choices for Reducing the Energy Consumption of Blockchain Technologies and Digital Currencies." Energy Research & Social Science 44 (October): 399–410.

[42] McIntyre, Douglas A. 2018. "Bitcoin May Accelerate Greenhouse Gas Problem - 24/7 Wall St https://247wallst.com/economy/2018/08/02/bitcoin-may-accelerate-greenhouse-gas-problem/.

but speculators do not tend to pause to reflect on their environmental footprints. Energy consumption goes up when their prices go up. According to Malmo (2017),[43] "Bitcoin's incredible price run to break over $7,000 this year has sent its overall energy consumption soaring, as people worldwide bring more energy-hungry computers online to mine the digital currency." Malmo asserts that "bitcoin miners burn through over 24 terawatt-hours of electricity annually as they compete to solve increasingly difficult cryptographic puzzles to 'mine' more Bitcoins. That's about as much as Nigeria, a country of 186 million people, uses in a year." Although it is extremely difficult to know how much electricity the bitcoin network uses, the authors estimate that the global Bitcoin mining represents a minimum of 77KWh of energy consumed per Bitcoin transaction: "As senior economist Teunis Brosens from Dutch bank ING wrote, it's enough to power his own home in the Netherlands for nearly two weeks." Malmo (2017) further notes that:

> "The problem is carbon emissions. De Vries has come up with some estimates by diving into data made available on a coal-powered Bitcoin mine in Mongolia. He concluded that this single mine is responsible for 8,000 to 13,000 kg CO2 emissions per Bitcoin it mines, and 24,000 - 40,000 kg of CO2 per hour. As Twitter user Matthias Bartosik noted in some similar estimates, the average European car emits 0.1181 kg of CO2 per kilometer driven. So for every hour the Mongolian Bitcoin mine operates, it's responsible for (at least) the CO2 equivalent of over 203,000 car kilometers travelled."

In another study, it was estimated that Bitcoin consumes as much energy as Ireland (O'Dwyer and Malone, 2014)[44]. Dilek and Furuncu (2019:7)[45] argued that "when comparing countries' electricity consumption and the energy consumed by Bitcoin mining, Bitcoin mining surpasses 175 countries in total, more than 20 European countries included, in terms of electricity consumption. Thus, the amount of energy used up for mining Bitcoin is more than the energy consumption of many countries. If considered within a sequence of countries, Bitcoin comes in 50th in terms of the amount of energy it consumes." Mishra (2017)[46] also notes that in a case where 400 transactions are completed per second, it has been calculated that Bitcoin mining requires 30,582 MW of energy per month. While some analysts are already ringing the alarm bell that bitcoin mining is on track to consume all of the world's energy by 2020,[47] others like Helman (2018)[48] have argued that this is clearly not a realistic picture. Even so, Helman (2018) notes that " bitcoin mining is already eating up an estimated 20,000 gigawatt hours of

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[43] Malmo, Christopher. 2017. "One Bitcoin Transaction Consumes As Much Energy As Your House Uses in a Week." Vice (blog). November 1, 2017. https://www.vice.com/en_us/article/ywbbpm/bitcoin-mining-electricity-consumption-ethereum-energy-climate-change.

[44] O'Dwyer J. K. and Malone D. (2014) "Bitcoin Mining and its Energy Footprint", Hamilton Institute, National University of Ireland Maynooth SSC 2014 / CIICT 2014, Limerick, June 26–27

[45] Dilek, Şerif, and Yunus Furuncu. 2019. "BITCOIN MINING AND ITS ENVIRONMENTAL EFFECTS." Journal of Economics and Administrative Sciences 33 (1): 91–106. http://dergipark.org.tr/atauniiibd/423056.

[46] Mishra S. P. (2017) "Bitcoin Mining and Its Cost", University of Texas at Dallas - Naveen Jindal School of Management

[47] Cuthbertson, Anthony. 2017. "Bitcoin's Meteoric Rise Is Very Bad News for the Environment." Newsweek. December 11, 2017. https://www.newsweek.com/bitcoin-mining-track-consume-worlds-energy-2020-744036.

[48] Helman, Christopher. 2018. "Bitcoin Mining Uses As Much Power As Ireland. Here's Why That's Not A Problem." Forbes. Accessed August 21, 2019. https://www.forbes.com/sites/christopherhelman/2018/01/16/bitcoin-mining-uses-as-much-power-as-ireland-and-why-thats-not-a-problem/.

electricity per year. That's roughly .1% of global generation, on par with the power demand of Ireland. The primary culprits are bitcoin mining appliances like the Antminer S9, which is a computer processor that does nothing but endlessly crunch algorithms to lengthen the blockchain."

As consumer demands for electronic gadgets and computers increase, energy consumption in the digital economy, especially ICT also increases. The global ICT, landscape "includes everything from smartphones to laptops to digital TVs to — especially — the vast and electron-thirsty computer-server farms that make up the backbone of what we call "the cloud." (Walsh, 2013).[49] In a report titled, "*The Cloud Begins With Coal: Big Data, Big Networks, Big Infrastructure and Big Power,*" which focuses on electricity used by the global digital ecosystem, Mills (2013:3)[50] stated that the world's information-communication-technologies (ICT) ecosystem uses about 1,500 terawatt-hours each year, "equal to all the electric generation of Japan and Germany combined—as much electricity as was used for global illumination in 1985." That's about 10% of the world's total electricity generation. In other energy terms, the modern world uses "about 50% more energy than global aviation." According to Mills (2013), the data created, used, and transported each year (referred to as the 'digital universe') is growing at a faster pace than at any time in history.

In an era described by Cisco (2013) as the 'zettabyte era',[51] "Global IP [internet protocol] traffic has increased fivefold over the past 5 years, and will increase threefold over the next 5years. Overall, IP traffic will grow at a compound annual growth rate (CAGR) of 21 percent from 2013 to 2018" (Cisco, 2013:2). Mills (2013) notes that global big data capital spending is now in the same league as big oil (global investment in the infrastructure of the digital economy is already over $5 trillion, and will grow another $3 trillion within a decade). However, while big oil produces energy, big data consumes energy, specifically electricity. Population growth and economic growth have become the key factors in the world's increasing energy demand — electricity in particular. Despite substantial gains in efficiency, overall global energy use will rise by an amount equivalent to adding two United States' worth of current demand by 2030 (Mills, 2013: 8).

In 2018,[52] Pew Research and Elon University's Imagining the Internet Center conducted a large-scale canvassing of technology experts, scholars, corporate and public practitioners on "The Future of Well-Being in a Tech-Saturated World". The key themes of this survey showed that policymakers need to pay attention to the nexus between digital revolution, artificial intelligence and the environment. For example, Marcus Foth, professor of Urban Informatics at Queensland University of Technology commented that "the increasing use of energy (e.g.,

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[49] Walsh, Bryan. 2013. "The Surprisingly Large Energy Footprint of the Digital Economy [UPDATE]." Time. Accessed August 21, 2019. http://science.time.com/2013/08/14/power-drain-the-digital-cloud-is-using-more-energy-than-you-think/.

[50] Mills, Park. 2013. The Cloud Begins With Coal: Big Data, Big Networks, Big Infrastructure and Big Power: An Overview of Electricity Used by the Global Digital Ecosystem. https://www.tech-pundit.com/wp-content/uploads/2013/07/Cloud_Begins_With_Coal.pdf

[51] Cisco (2013). The Zettabyte Era—Trends and Analysis. https://www.aclu.org/sites/default/files/field_document/77-4._lee_declaration_part_ii_8.6.15.pdf
Note that the unit zetta is a tera times one billion; a zetta--stack of dollar bills would reach the sun and back --- one million times (Mills 2013).

[52] Pew Research and Elon University's Imagining the Internet Center. 2018 http://www.elon.edu/e-web/imagining/surveys/2018_survey/Digital_Life_and_Well-Being_credit.xhtml

cloud computing, blockchain, et cetera), rare earth metals, the unregulated mining of cobalt to produce lithium ion batteries, etc., in combination with planned obsolescence cause ever increasing environmental problems (e-waste, climate change, et cetera)." Sy Taffel, senior lecturer in Media Studies at Massey University also wrote that "the world will continue to become more automated, digitally connected and filled with an array of digital devices as the Internet of Things really takes off. There will be significant improvements in areas such as health care, education and entertainment, particularly driven by advances in machine learning and AI, however, there are likely to be significant issues around surveillance, loss of work, algorithmic discrimination and environmental damages associated with digital technology."[53]

Sustainable development and The Green Economy Agenda

The Brundtland Commission report, Our Common Future, defined sustainable development as:

> Development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:
> o the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and
>
> o the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs (World Commission on Environment and Development 1987, 44).[54]

Although it has now been over three decades since this conceptualization of sustainable development, it has influenced several normative frameworks and stakeholders, including corporate leaders and policymakers. Lins and Horwitz (2007, 16)[55] explain that following the Brundtland Commission report, the Rio de Janeiro Earth Summit that was held in 1992 enabled sustainability issues to move "from the fringe to the mainstream." They highlighted that the three pillars of sustainable development that emerged at the summit — economic, environmental and social, regarded as the 'triple bottom line'— served as the driving force for industry growth and risk minimization. What has become more notable is the addition of 'governance' to the triple bottom line, hence 'triple bottom line plus one'(Lins and Horwitz 2007).

Although there is no universal definition of the concept of sustainable development, it generally focuses on human well-being: distributing wealth in ways that reduce poverty; balancing economic growth with social development and environmental sustainability; and factoring in the important contributions of technology and social organizations in human and natural resource development (Inter-

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[53] Ibid.

[54] "Our Common Future." 1987. World Commission on Environment and Development.

[55] Lins, Clarissa, and Elizabeth Horwitz. 2007. Sustainability in the Mining Sector. Fundação Brasileira para o Desenvolvimento Sustentável. http://www.fbds.org.br/IMG/pdf/doc-295.pdf.

national Institute for Sustainable Development 2010, 4[56]).

In the last decade, the green economy discourse has been linked to the historic 2030 Agenda for Sustainable Development (Global Goals), which was adopted in 2015 by the 193-member states of the United Nations (UN). Kenis and Lievens (2015)[57] have provided an overview of the discourse surrounding the green economy. They noted that following the failure of the 2009 UN climate summit in Copenhagen, international environmental talks were in tatters, so it seemed. Yet, about a week later, on December 24th 2009, the UN General Assembly adopted a resolution which launched the preparations for the Rio+20 summit. This international meeting would consecrate an ideological development that was already making headway during and before the Copenhagen summit: "the rise of so-called green economy thinking. Since then, this notion has gained centre stage in the international conversation on environmental policies, rapidly filling the gap left by the failure of Copenhagen."

At the heart of the green economy agenda is the need to reconcile economic growth with environmental protection. The United Nations Environment Programme (UNEP) has defined the green economy as "the process of reconfiguring businesses and infrastructure to deliver better returns on natural, human and economic capital investments, while at the same time reducing greenhouse gas emissions, extracting and using less natural resources, creating less waste and reducing social disparities." (UNEP, 2010, p.5)[58]. Businesses, especially technology giants that have been reliant on the cloud, must take steps to reduce negative environmental footprints. For instance, Facebook claims "we are on our way to reducing our greenhouse gas emissions by 75% and powering our global operations with 100% renewable energy by the end of 2020" (Facebook, 2018).[59] Google claims it has already achieved that goal, and so does Apple (Harris, 2018)[60]. Yet, beneath many of these claims lies a reality in which the constant demand for power means that these companies increasingly rely on energy generated by fossil fuels, including coal (Harris, 2018).

The Digital Economy Agenda and Green Economy: Compatible Visions?

Although policymakers and business actors are making efforts in the green economy area (e.g., discourses around a global green new deal), the pace of action has been generally slow compared to the exponential acceleration in technological change, data usage, and energy

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[56] International Institute for Sustainable Development. 2010. "The Digital Economy and the Green Economy: Opportunities for Strategic Synergies. A Submission to the Digital Economy Consultation," 23. https://www.iisd.org/pdf/2010/com_digital_economy.pdf.

[57] Kenis, Anneleen, and Matthias Lievens. 2015. The Limits of the Green Economy: From Re-Inventing Capitalism to Re-Politicising the Present. 1 edition. Abingdon, Oxon ; New York, NY: Routledge.

[58] UNEP. (2010). Green Economy Report: A Preview, United Nations Environment Programme. https://unep.ch/etb/publications/Green%20Economy/GER%20Preview%20v2.0.pdf

[59] Facebook. 2018. "On Our Way to Lower Emissions and 100% Renewable Energy." 2018. https://newsroom.fb.com/news/2018/08/renewable-energy/.

[60] Harris, John. 2018. "Our Phones and Gadgets Are Now Endangering the Planet | John Harris." The Guardian, July 17, 2018, sec. Opinion. https://www.theguardian.com/commentisfree/2018/jul/17/internet-climate-carbon-footprint-data-centres.

consumption. Without urgent system-wide action, it will be impossible for the two agendas (digital economy and a sustainable human trajectory) to be compatible. Even so, Ciocoiu (2011:8)[61] notes that opportunities for synergy between digital economy and green economy strategies have been widely recognized in developed countries. The author notes that over the past 5–10 years, a consensus has emerged that ICTs can support the development of the green economy in three principal ways:

1. By decreasing direct effects on the environment of the production, distribution, operation and disposal of ICTs through improved energy and materials efficiency, increased use of renewable energy sources, reduced use of toxic materials and improved recycling and end-of life disposal of ICTs;

2. By increasing the enabling effects of ICTs on the development of the green economy through improvements in the efficiency of production, distribution and consumption of goods and services throughout the economy and society; by reducing demand for energy and materials through the whole or partial substitution of virtual products and services for their physical equivalents; and through the dematerialization of human activities and interactions. The largest influence of ICT is likely to be in enabling energy efficiencies in other sectors. According to Climate Group (2008),[62] these could generate CO2 emissions savings five times greater than the total emissions from the entire ICT sector in 2020 Up to 30 percent of energy savings worldwide are possible through better monitoring and management of electricity grids (Climate Group, 2008);

3. By supporting systemic effects that result in the transformation of behaviour, attitudes and values of individuals as citizens and consumers; economic and social structures; and governance processes. The ICT industry, in partnership with other sectors, has a key role to play in helping to make society's impact visible and to demonstrate the demand for new ways of reducing that impact.

Despite these opportunities for synergies, it is important to pause, reflect, and rethink the current trajectory of the digital and green agendas. The digital economy is accelerating faster than the actions being taken in the green economy movement to counter negative environmental impacts. In the article, "The Battle for New Resources: Minor Minerals in Green Technologies," Abraham (2012)[63] argues that green technology can make countries more energy secure; "however, the reality is stark: the world cannot meet projected green technology demands with its current rare mineral supply." As nations begin to rely on green energy products, they are trading one set of resource dependencies for another. He observed that despite the importance of green technology to the future of global power generation, very little analysis to date has outlined the geopolitical repercussions of shifting reliance on traditional fossil fuels to an undefined mix of alternative energy sources. Addressing demands in rare earth metals should focus on R&D investments, recycling, and encouraging better product design.

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[61] Ciocoiu, Carmen Nadia. 2011. "Integrating Digital Economy and Green Economy: Opportunities for Sustainable Development." Theoretical and Empirical Researches in Urban Management 6 (1): 33.

[62] Climate Group and the Global eSustainability Initiative, (2008). SMART 2020: Enabling the Low Carbon Economy in the Information Age. Retrieved September, 2010, from http://www.smart2020.org/_assets/files/02_Smart2020Report.pdf.

[63] Abraham, David. 2012. "RIETI - The Battle for New Resources: Minor Minerals in Green Technolo-

Furthermore, in the article “Linking Economic Growth Pathways and Environmental Sustainability by Understanding Development as Alternate Social-Ecological Regimes”, Cumming and von Cramon-Taubadel (2018)[64] argued that scientists understand how global ecological degradation is occurring but not why it seems to be so difficult to reverse. The authors utilized national-level data and a mathematical model to provide an empirical test of the hypothesis that national economies display two distinct economic regimes that are maintained by self-reinforcing feedbacks between natural resources and society:

> “Our results not only support previous findings that two distinct groups exist, but also show that countries move toward one of these two different equilibrium points because of their different patterns of natural resource use and responses to population growth. At the less economically developed equilibrium point maintained by “green-loop” feedbacks, human populations depend more directly on ecosystems for income. At the more economically developed equilibrium point maintained by ‘red-loop’ feedbacks, nonecosystem services (e.g., technology, manufacturing, services) generate the majority of national gross domestic product (GDP), but increasing consumption of natural resources means that environmental impacts are higher and are often exported (via cross-scale feedbacks) to other countries. Feedbacks between income and population growth are pushing countries farther from sustainability. Our analysis shows that economic growth alone cannot lead to environmental sustainability and that current trajectories of resource use cannot be sustained without breaking feedback loops in national and international economies” Cumming and von Cramon-Taubadel (2018:1).

“The idea that the current production and consumption pattern is leading us to a disaster is becoming increasingly accepted. Evidence that the economy is in conflict with the earth’s natural systems can be seen in the daily news reports of collapsing fisheries, shrinking forests, eroding soils, disappearing species (Brown, 2003[65] p.14, cited in Nascimento, 2012[66]). Nascimento (2012) notes that “there is almost unanimity among scientists today that natural resources will not be sufficient to ensure a way of life similar to that of the world middle class to all new market entrants.”

What Can be Done?

In his 2008 book, “Hot, Flat, and Crowded: Why We Need a Green Revolution-- and How It Can Renew America”,[67] Thomas Friedman, noted that “there is only one thing bigger than Mother Nature and that is Father Profit. [W]e have not even begun to enlist him in this struggle” (Fried-

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gies.” 2012. https://www.rieti.go.jp/en/publications/summary/12030010.html

[64] Cumming, Graeme S., and Stephan von Cramon-Taubadel. 2018. “Linking Economic Growth Pathways and Environmental Sustainability by Understanding Development as Alternate Social-Ecological Regimes.” Proceedings of the National Academy of Sciences of the United States of America 115 (38): 9533–38. https://doi.org/10.1073/pnas.1807026115.

[65] Brown, L. R. *Éco-économie, une autre Croissance est Possible, Écologique et Durable*. Trad. Denis Trierweiler. Paris: Seuil, 2003.

[66] Nascimento, Elimar Pinheiro do. 2012. “The Trajectory of Sustainability: From Environmental to Social, from Social to Economic.” Estudos Avançados 26 (74): 51–64. https://doi.org/10.1590/S0103-40142012000100005.

[67] Friedman, Thomas L. 2008. Hot, Flat, and Crowded: Why We Need a Green Revolution-- and How It Can Renew America. 1st ed. New York: Farrar, Straus and Giroux.

man 2008, 244). Friedman argued that it is important to utilise market mechanisms and the innovative nature of capitalism to make the transition to a green future. The market will have to be corrected by governments in order to price externalities and make polluting products more expensive than environmentally friendly alternatives. Any correction will do, according to Friedman, whether it is a carbon tax, a gasoline tax, or a cap and trade system, "as long as the effective tax is high enough and long-term enough to really change behaviour" (Friedman 2008, 261). He states that the U.S has the opportunity to display global leadership through the green economy agenda: "Making America the world's greenest country is not a selfless act of charity or naive moral indulgence. It is now a core national security and economic interest" (Friedman 2008, 23). While Friedman's approach is US-centric, Nascimento (2012) takes a broader perspective:

> "The first answer is technology, which blames the ingenuity of man for the announced depletion of natural resources. The second lies in the extreme (but progressive) change in the existing production and consumption pattern expressed in the degrowth movement, among others. The third is the possibility of not being able to avoid the catastrophe that could gradually lead to the extinction of humanity. This would be the non-answer.… The third answer lies in the possibility of a catastrophe. In fact, it is the result of a non-answer. The idea that the problems heralded by the environmental crisis can be solved through technological innovation cannot be right. It is true that several initiatives are being currently undertaken in the attempt to replace fossil energy sources. Germany and the countries in northern Europe are examples of that. However, greenhouse gas emission is already considerable, and measures to reduce it are slow. It is a race against time. And the belief that humanity has always known how to overcome natural difficulties through new technologies is no guarantee that this will occur in the future. Ideas such as creating bacteria that can absorb carbon dioxide or putting mirrors in the stratosphere to reflect sunlight and reduce solar heat are dangerous from the standpoint of their consequences, and uncertain as to their viability. In turn, it is possible that climate change will accelerate, to the extent that global warming will release more of the CO2 that is retained in nature (permafrost in Siberia and the Arctic, for example). A sudden reversal in climate can have catastrophic effects on human life, and this may already be occurring, with results to be felt in the next two or three decades."

For the digital carbon footprint, Strubell and colleagues (2019) advocate for the "creation of cloud services by the government (specifically for researcher use) and to explore more efficient (less costly) algorithms, along the lines of supercomputing resources available to the research community in the past."[68] They also suggested that academic researchers need equitable access to computation resources, and researchers should prioritize computationally efficient hardware and algorithms. The latter suggestion is meant to help reduce the energy and CO2 emission associated with AI model training. Schwab and colleagues (2018:221)[69] argue that the complex, transformative and distributive nature of the Fourth Industrial Revolution demands a new type

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[68] Jagannathan, Juggy. 2019 "AI Talk: Avatars, Carbon Footprint and Manufacturing AI." 3M Inside Angle. Accessed August 21, 2019. https://www.3mhisinsideangle.com/blog-post/ai-talk-avatars-carbon-footprint-and-manufacturing-ai/.

[69] Schwab, Klaus, Nicholas Davis, and Satya Nadella. 2018. Shaping the Future of the Fourth Industrial Revolution. New York: Currency.

of leadership — systems leadership:

> “Systems leadership is about cultivating a shared vision for change — working together with all stakeholders of global society—and then acting on it to change how the system delivers its benefits, and to whom. Systems leadership is neither a call for top-down control, nor for subtle influence by powerful groups, but rather a paradigm that empowers all citizens and organization to innovate, invest and deliver value in a context of mutual accountability and collaboration. Ultimately, it’s a set of interconnected activities that have the goal of shifting the structures of our social and economic systems to succeed in an area where previous industrial revolutions have failed—to deliver sustainable benefits to all citizens, including for future generations.”

Systems leadership can be broken down into three areas of focus: technology leadership, governance leadership and values leadership. For technology leadership, the authors explained that the fact that all Fourth Industrial Revolution technologies rely and build on digital systems means ensuring that, as much as possible, organizations are investing in digital communication and collaboration tools, data management and cybersecurity:

> “Just like oil, a leak of data can be catastrophic. In fact, the combination of new computing approaches, AI and an expanding set of use cases for personal data is accelerating cyber risks at an alarming rate. As with oil, there are important reasons to protect data, but to make the most of this resource, we must find ways to treat data as a collective asset to be used for the common good, rather than a privatized resource that is fully transferred and exploited by a few powerful organizations.” (Schwab et. al, 2018:225).

Governance leadership relates to formal structures for creating laws and regulations. It entails “the development and use of standards, the emergence of social norms that can constrain or endorse use, private incentive schemes, certification and oversight by professional bodies, industry agreements and the policies that organizations apply voluntarily or by contract in their relationships with competitors, suppliers, partners and customers.” (Schwab et. al, 2018:224). It requires leaders to rethink “what we govern, and why.” It also requires moving beyond the ‘what’ of governance and to rethink the ‘how’.

Values leadership goes beyond investing in better technology leadership and new models of governance: “No matter our agendas, the importance of preserving the planet for future generations, the value of human life, the international principles of human rights, and a sincere concern for global commons issues can serve as starting points for recognizing that the true ends of technological development are ultimately and always the planet and its people.” (Schwab et. al, 2018:228).

CONCLUDING REMARKS

The governance ecosystems of the 21st century is characterized by accelerating rate of technological change. The velocity and scope of this change will likely continue to increase. We are standing at the "edge of a new frontier"[70] — the frontier of exponential technological change, hypoconnectivity, and uncertainty. It is simply "a different world from the one faced by prior generations of public sector leaders and decision-makers" (Bourgon, 2017:41).[71] This reality calls for a different way of thinking and a different way of doing things.

In the past decade, the digital economy and the green economy have become important policy agendas for governments. While a significant attention has been given to the promises and perils of the digital economy, little attention has been given to the compatibility of both agendas. In an extensive and recent review of the literature on the future of environmental un(sustainability), Kuntsman and Rattle (2019: 568)[72] argued that although the materiality of digital technologies inflicts substantial environmental damage through resource extraction practices, toxicity of e-waste and increasing energy demands, "this damage, however, is paradoxically under-theorized in scholarship on environmental sustainability.… we see very little critical consideration of the question of whether, and to what extent, the digital itself is environmentally sustainable." They note that despite the existing critique of the "techno-fix" approach in sustainability studies, digitalization continues to be celebrated as the tool for environmental sustainability; an approach they referred to as "digital solutionism." They asserted that "a matrix of blind spots" — which they characterized as a "paradigmatic myopia" — exists in the conversation on digital technologies and sustainability. The authors suggest that "the myopia around digital harms, built into digital solutionism, needs to be understood as simultaneously engrained in the power of the global digital economy and in cultural beliefs and media practices that accompany and sustain it." (Kuntsman and Rattle (2019: 578).

As highlighted by scholars such as Gould (2016)[73] and Chen (2016),[74] the digital economy rests on "planned obsolescence"— that is, devices are designed to have a short life span and to be replaced frequently. Gould (2016) highlights that planned obsolescence is reinforced through consumer behaviour and 'symbolic annihilation'— that is, a framing in which digital technologies are glorified while information about their environmental damages become invisible. This often occurs when technology giants like Apple and the media consistently minimise or bury stories of e-waste and envi-

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[70] Kennedy, John F. 1960. "Acceptance of Democratic Nomination for President | JFK Library." July 15, 1960. https://www.jfklibrary.org/learn/about-jfk/historic-speeches/acceptance-of-democratic-nomination-for-president.

[71] Bourgon, Jocelyne. 2017. "The New Synthesis of Public Administration Fieldbook". Copenhagen, Dansk Psykologisk Forlag A/S.

[72] Adi Kuntsman & Imogen Rattle (2019). Towards a Paradigmatic Shift in Sustainability Studies: A Systematic Review of Peer Reviewed Literature and Future Agenda Setting to Consider Environmental (Un)sustainability of Digital Communication, Environmental Communication, 13:5, 567-581.

[73] Gould, A. S. (2016). Restor(y)ing the ground: Digital environmental media studies. Networking Knowledge: Journal of the MeCCSA Postgraduate Network, 9(5), 1–19.

[74] Chen, S. (2016). The materialist circuits and the quest for environmental justice in ICT's global expansion. tripleC: Communication, Capitalism & Critique. Open Access Journal for a Global Sustainable Information Society, 14(1), 121–131. doi: 10.31269/triplec.v14i1.695

ronmental damages associated with devices like iPhones, which are branded as iconic products. Abraham (2017)[75] also examines these themes in The Elements of Power. On obsolescence, he notes:

> "The amount of electronic waste the world is producing is growing at an estimated 17 percent annually, even though total amount of waste collection in some countries has leveled. We are on a global trajectory to toss out over a billion computers annually. This is not just because we have more of these devices but because we use them so briefly. The average lifecycle of a smartphone is about twenty-one months. Likewise, laptops, tablets, and many of our high-tech gadgets have life spans of less than three years. This is not because the product is useless when we junk it but because its obsolescence, in many cases, is by design" (Abraham, 2017:215).

Abraham also sheds some light on the life cycle of modern gadgets and energy usage:

> "Every step in the life cycle of our gadgets—production, use, and disposal—produces greenhouse gases. But as consumers, we don't see the emissions. Unlike the short tailpipe on our cars, the long tailpipe of our high-tech lives obscures its exhaust. We might assume that the greatest amount of electricity used and its subsequent contribution to greenhouse gases occurs when a gadget is in our hands or in a wall charger. After all, it's the only use of electricity we see. But Nokia and Apple found that a mere 15 percent of the greenhouse gases generated by the entire life cycle of many of their products come from the electricity needed to charge them. This means that roughly 85 percent comes from their manufacturing, shipping, and disposal.…To understand a product's true environmental impact, we must also consider the pollution generated from manufacturing and disposal" (Abraham, 2017:177).

The above examples reinforce the fulsome discussions in the various sections of this paper—which focused on rare earth extraction, coal, digital ecosystems (data centres, AI models, bitcoins and energy consumption) and their impact on the environment, as well as compatibility between the digital economy and the green economy. The paper asserts that although efforts are being made to find synergies between the digital economy and green economy agendas, the pace of action on the green economy has been generally slow compared to the exponential acceleration in the digital economy. Without urgent system-wide and societal actions from governments, it would be impossible for the two agendas (digital economy and green economy) to become compatible.

In contending that "a matrix of blind spots" exist around the digital economy and sustainability, Kuntsman and Rattle (2019:568) called for "a paradigmatic shift in environmental sustainability studies, towards accounting for the environmentally unsustainable nature of the very digital tools, brought to provide sustainable solutions." This entails expanding the discourse on environmental governance to include environmental footprint of digital communication technologies and shifting our mindset from digital solutionism to critical accountability. More specifically, the authors proposed the following:

> "A systematic account of global and local material damages of devices, platforms and data systems adopted into sustainability research and practice, resulting in changes in both research fram-

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[75] Abraham, David S. 2017. The Elements of Power: Gadgets, Guns, and the Struggle for a Sustainable Future in the Rare Metal Age. Reprint edition. Yale University Press.

> ing (where environmental harms of digital solutions would be a starting point of any investigation, rather than an afterthought) and subsequent methodological foundations and empirical [facts.…] We should develop a more accountable perspective on the global complexity of potential perils and harms of some sustainability agendas. And it will also require a transdisciplinary dialogue with other fields.”
> (Kuntsman and Rattle 2019:579)

These views are consistent with the New Synthesis Initiative (NS). The NS Framework and the NS Exploratory Cycle blend systems theory, adaptive system thinking and complexity theory to encourage exploration and invention of viable and pragmatic solutions to complex issues. It brings together in a coherent whole insight from different disciplines. From a NS perspective, the magic is not in the various elements but instead in how all the pieces can be brought together to generate a new and emergent reality. New Synthesis (NS) framework helps public sector leaders to identify the most important lines of inquiry. It is “a tool that can help practitioners examine and challenge their assumptions and explore the full range of options at their disposal… [it] help[s] to reveal the implications that various choices entail” for society, across sectors and over time (Bourgon, 2011: 33). NS calls for a broader mental map that encompass all aspect of life in society and a dynamic approach to collective problem solving that brings together an integrated whole the role of government, people and multiple agents in society.

Framing issues around the digital economy and its environmental impact must move from a narrow perspective (i.e. industry level; agency level) to framing in ‘broad societal terms’ (Bourgon, 2011). This would help to expand the scope of innovation. Overall, “the challenge is to explore what can be done, using the resources and capabilities currently available, to move up the value chain of public results. This means generating better government-wide, system–wide and societal results” (Bourgon, 2017:73). Perhaps, the way to move the current discussion forward is to reframe the question as: What needs to be done to set the world on a sustainable human trajectory?

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NS is an international co-operation initiative led by The Honourable Jocelyne Bourgon P.C., O.C.