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Cryptocurrencies and Climate Change: A Net-Zero Paradox

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Cryptocurrencies pose a number of complex law and policy problems, the most pressing of which are the industry's climate and environmental impacts. This article examines the climate and environmental impacts of crypto-assets in the broader law and policy context of the UN Paris Agreement and the global goal of reaching net-zero emissions by 2050 or earlier. This approach not only illuminates the limitations and paradoxical nature of the crypto-industry's climate commitments, but also the limitations and paradoxical nature of "net zero" itself as the predominant framing of national, subnational, and nonstate actors' climate pledges. The article concludes by examining the crypto-industry's climate and environmental impacts and decarbonization strategies through the lens of "limits to growth" and the possibility that perpetual economic growth and environmental protection are fundamentally incompatible.

> *I'd love to have an NFT [nonfungible token], but it feels like I'm burning a forest down.*[1]

I. INTRODUCTION

Scholarly analysis of the cryptocurrency industry faces a fundamental challenge: How can analysts carefully examine and accurately report on such a volatile and fast-changing industry? As of this writing, for example, the news media reports that the "cryptocurrency industry has endured a terrible year. A devastating crash wiped nearly $1 trillion from the market, draining the savings of thousands of people. Several companies filed for bankruptcy."[2] The

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[1] This is how a crypto software developer, Preston Van Loon, characterizes the growing cognitive dissonance created by the popularity of crypto-tokens and their extraordinary environmental impacts. Quoted in David Yaffe-Bellany, "The Crypto World Can't Wait for 'the Merge,'" *The New York Times* (26 August 2022), online: <www.nytimes.com/2022/08/26/technology/crypto-ethereum-the-merge.html> [Yaffe-Bellany, "Crypto World Can't Wait"].

[2] *Ibid*. This is to say nothing of the FTX bankruptcy and the fraud allegations leveled

implications of this downturn, including its implications for the regulation of cryptocurrencies, are highly uncertain.

The same can be said about the industry's climate and environmental impacts. Industry enthusiasts insist that blockchain and crypto products will usher in a decentralized Internet and change the economics of banking, finance, gaming, shopping, entertainment, and even human interaction.[3] But in 2021, serious concerns emerged about the industry's environmental impacts, including extraordinarily high levels of energy use and electronic waste, and those concerns have since grown louder. China recently prohibited the exchange of crypto-assets and the process of crypto-mining, *i.e.,* the process of creating, verifying, and storing new digital tokens, discussed in more detail below, due to its high energy demand, which resulted in the revival of previously closed coal mines and power plants.[4] Criticisms that the industry's adverse climate and environmental impacts outweigh its potential benefits have become widespread.[5] One economic study concluded that for each cryptocurrency, rising electricity requirements to produce a single coin can lead to "an almost inevitable cliff of negative social benefits."[6] The study found, for example, that in December 2018, the human health and climate change "cryptodamages" for Bitcoin roughly matched each $1 of coin value created.[7] Corresponding calls for regulation are increasing: "Regulating this largely gambling-driven source of carbon emissions appears to be a simple means to contribute to decarbonizing the economy."[8] The US Office of Science and Technology Policy, which provides scientific, engineering, and technology advice to the US President and others within the Executive Office of the President, recently warned that, "[d]epending on the energy intensity of the technology used, crypto-assets could hinder broader efforts to achieve net-zero carbon pollution consistent with U.S. climate commitments and goals."[9]

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against Sam Bankman-Fried, developments which unfolded after this article went to press.

3 Ephrat Livni, "Can Crypto Go Green?" *The New York Times* (11 October 2021), online: <www.nytimes.com/2021/10/10/business/dealbook/crypto-climate.html>.

4 Hiroko Tabuchi, "China Banished Cryptocurrencies. Now, 'Mining' Is Even Dirtier," *The New York Times* (25 February 2022), online: <www.nytimes.com/2022/02/25/climate/bitcoin-china-energy-pollution.html>; Livini, *ibid.*

5 Yaffe-Bellany, "Crypto World Can't Wait," *supra* note 1. See also Kevin Roose, "The Latecomer's Guide to Crypto," *The New York Times* (18 March 2022), online: <www.nytimes.com/interactive/2022/03/18/technology/cryptocurrency-crypto-guide.html>.

6 Andrew L Goodkind, Benjamin A Jones & Robert Berrens, "Cryptodamages: Monetary value estimates of the air pollution and human health impacts of cryptocurrency mining" (2020) 59 Energy Research & Social Science 101281.

7 *Ibid.*

8 Andrew Ross Sorkin, "Bitcoin's Climate Problem," *The New York Times* (9 March 2021), online: <www.nytimes.com/2021/03/09/business/dealbook/bitcoin-climate-change.html> quoting from Christian Stoll, Lena KlaaBen & Ulrich Gallersdörfer, "The Carbon Footprint of Bitcoin" (2019) 3 Joule 1647 at 1655-1656.

Yet, as of this writing, the industry's environmental profile may be about to change dramatically. The industry, or at least a significant segment of it, is presently celebrating the long-awaited software upgrade to the most popular cryptocurrency blockchain, Ethereum, on which the second-most-valuable cryptocurrency, Ether, is exchanged. Ethereum previously operated a software framework known as "proof of work," which is extraordinarily energy intensive (this is discussed in detail below); Ethereum's carbon footprint was roughly equivalent to that of Finland.[10] Since 2014, software engineers have been working on moving Ethereum to a more energy-efficient framework referred to as "proof of stake," a system based not on competition but rather consensus that would eliminate the need for high computational power to verify transactions.[11] Late in 2020, software engineers introduced a version of this new blockchain called the Beacon Chain, and as of this writing, the Beacon Chain has finally merged with the original Ethereum blockchain after several setbacks and delays.[12] This long-awaited "Merge" is widely expected to reduce Ethereum's energy use by as much as 99 percent.[13]

But the alternative to the proof-of-work system, which remains the system used by the most popular and valuable cryptocurrency, Bitcoin, is not without critics, particularly industry incumbents deeply invested in expensive proof-of-work mining infrastructure, as well as those who observe that very few investors will be able to afford to buy into Ethereum's new lottery system for verifying transactions.[14] Neither will a consensus-based proof-of-stake system be able to deliver the decentralized, democratized Internet originally promised by blockchain,[15] nor the corporate accountability and transparency promoted by corporate social responsibility (CSR) scholars and advocates.[16] Nor, for that matter, will the "Merge" necessarily cause industry incumbents to switch

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9 Office of Science and Technology Policy, *Climate and Energy Implications of Crypto-assets in the United States* (Washington, DC: White House Office of Science and Technology Policy, 8 September 2022) at 4, online (pdf): <www.whitehouse.gov/wp-content/uploads/2022/09/09-2022-Crypto-Assets-and-Climate-Report.pdf>.

10 David Yaffe-Bellany, "What Is 'the Merge'?" *The New York Times* (26 August 2022), online: <www.nytimes.com/2022/08/26/technology/what-is-the-merge.html> [Yaffe-Bellany, "What Is 'the Merge'?"].

11 *Ibid.*

12 David Yaffe-Bellany, "Crypto's Long-Awaited 'Merge' Reaches the Finish Line," *The New York Times* (15 September 2022), online: <www.nytimes.com/2022/09/15/technology/ethereum-merge-crypto.html>.

13 *Ibid.*

14 After the Merge, Ethereum "stakers" will need to pay 32 Ether — approximately US$54,000 — to enter the lottery: *ibid.* This will presumably have a centralizing, rather than decentralizing, effect on the platform.

15 The *locus classicus* is Satoshi Nakamoto, "Bitcoin: A Peer-to-Peer Electronic Cash System" (2008), online (pdf): <bitcoin.org/bitcoin.pdf>.

16 See e.g., Lucas Mathieu & Richard Janda, "Made in Everywhere: Transformative Technologies and the (Re)codification of CSR in Global Supply Chains" in Oonagh E

networks and adapt their business models, let alone cease trading in proof-of-work cryptocurrencies, including Bitcoin. Thus does the highly technical and esoteric "Merge" present the now-familiar predicament of moving rapidly toward a net-zero global economy, which requires not only significant behavioural changes, but also the radical restructuring of entire industries, and perhaps the outright *retirement* of others.

The "Merge" is accordingly much more than the latest example of cryptocurrencies' inherent volatility and continuously changing nature. The "Merge" not only brings the climate and environmental problems posed by cryptocurrencies into clear relief, but it also suggests that there is something perhaps paradoxical about efforts to transform crypto into a net-zero greenhouse gas (GHG) emissions industry.[17] Reaching net-zero GHG emissions is not altogether unlike Zeno's paradox of motion. Recall that in Zeno's paradox, in order to get from point A to point B, a runner first runs 1/2 of the way. Before that, though, she must run 1/4 of the way, and before that, she must run 1/2 of 1/4 of the way (*i.e.,* 1/8, and before that 1/16), and she must do so *ad infinitum*. This means that the first part of her run is never completed. It also means that her run will take an infinite amount of time; therefore, paradoxically, it will never be completed at all.[18] So it is, I will argue in this article, with racing toward net-zero GHG emissions by the year 2050 (or earlier) while simultaneously striving for continuous economic growth — the race has yet to start, we are already lagging behind, and at this pace we will never get there.[19]

This article is in three parts. In the next part, I will briefly introduce the meaning of net-zero GHG emissions as a social-scientific concept and public-policy objective. I will proceed in the next parts by discussing the climate and environmental impacts of cryptocurrencies within the broader net-zero emissions law and policy context, followed by the paradoxical nature of crypto's specific net-zero commitments. In a brief conclusion, I put the paradoxes of net-zero emissions and the crypto-industry's climate commitments into the still larger context of environmental limits to perpetual economic growth.

Fitzgerald, ed, *Corporate Citizen: New Perspectives on the Globalized Rule of Law* (Waterloo, ON: Centre for International Governance Innovation, 2020) 123.

17 This is the express purpose not only of the "Merge," but also of the broader, industry-wide "Crypto Climate Accord," a voluntary industry-based initiative discussed below.

18 Nick Huggett, "Zeno's Paradoxes" in Edward N Zalta, ed, *Stanford Encyclopedia of Philosophy* (Winter 2019 edition), online: . See also Bertrand Russell, *Introduction to Mathematical Philosophy* (London: George Allen and Unwin Ltd., 1919).

19 At this writing, the most up-to-date data show that the atmospheric concentration of heat-trapping greenhouse gases (including carbon dioxide, methane, and nitrous oxide), along with sea-level rise and ocean temperatures, reached record highs in 2021. See Jessica Blunden & Tim Boyer, eds, "State of the Climate in 2021" (August 2022) 103:8 Bull American Meteorological Society Si-S465, online (pdf): <ametsoc.net/sotc2021/Chapter%201-BAMS-SoC2021-final.pdf>.

II. CRYPTO'S CLIMATE CONTEXT: NET ZERO IS NOT ZERO

Under the 2015 Paris Agreement on climate change, 197 countries agreed to limit global warming above the pre-industrial norm to well below 2 °C and to pursue efforts to limit warming to 1.5 °C. In order to have a 50 percent chance of limiting warming to 1.5 °C, global GHG emissions must not exceed 500 gigatonnes of carbon dioxide ($GTCO_2$); for a 67 percent chance, the global carbon budget shrinks to 400 $GTCO_2$; for an 83 percent chance, it shrinks again to 300 $GTCO_2$.[20] Staying within this tight global carbon budget requires global CO_2 emissions to peak before the year 2030 and fall to net zero near 2050.[21] Net zero means that anthropogenic carbon flows to and from the atmosphere are balanced in the aggregate.[22] This balancing requires a rapid and radical reduction in fossil-fuel and land-use-related carbon emissions as well as an increase in geological and biological carbon sinks.[23] In principle, net zero can be achieved through different balances of residual — *i.e.,* remaining, unabated, *not-zero* — emissions and different forms of carbon removal projects, both technological and nature-based.[24] There is a strong social-scientific case, however, for a net-zero carbon balance that combines a very low level of residual emissions with low levels of multi-decadal carbon removals from the atmosphere.[25] Moreover, because total anthropogenic global warming is a function not only of CO_2 but also a range of other GHGs, including methane and nitrous oxide, and because these GHGs are generally shorter lived but also more impactful on climate, net-zero policies should prioritize the rapid and radical reduction of GHG emissions.[26]

At this writing, more than 120 countries have pledged to reach net zero in some shape or manner by mid-century or thereabout, including China, the European Union, the United States, and Canada. Subnational and nonstate actors are also pledging net-zero emissions by or before 2050, including more than 100 regional governments, 800 cities, and 1,500 companies, including 20 percent of companies on the Forbes Global 2,000 List.[27] Along with its growing

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20 Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2021: The Physical Science Basis: Summary for Policy Makers* (2021) at 38, online: <www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf>.

21 Sam Fankhauser et al, "The meaning of net zero and how to get it right" (2022) 12 Nature Climate Change 15.

22 *Ibid.* at 16.

23 *Ibid.*

24 *Ibid* at 17.

25 *Ibid.* See also Jason MacLean, "Canada needs to cut carbon, not try to capture it," *The Conversation* (9 February 2022), online: <theconversation.com/canada-needs-to-cut-carbon-not-try-to-capture-it-175987>.

26 Fankhauser et al, *supra* note 21 at 16.

27 *Ibid.* at 16-17. For an analysis of this climate policy trend, see Jason MacLean, "Rethinking the Role of Nonstate Actors in International Climate Governance" (2020) 16:1 Loy U Chicago Intl L Rev 21. See also Jason MacLean, "Reorienting the Role of

normative importance, a burgeoning interdisciplinary literature on the meaning of net zero has emerged, offering guidance on the implementation of net-zero commitments. Climate researchers have identified a series of attributes of credible net-zero emissions plans: (1) front-loaded emissions reductions (reducing emissions as much and as fast as possible);[28] (2) a comprehensive approach to emissions reductions (addressing all GHG emissions, not only carbon emissions);[29] (3) cautious use of carbon dioxide removals (a combination of a very low level of residual emissions with low levels of multi-decadal removals of residual emissions from the atmosphere);[30] (4) effective regulation of carbon offsets (transparent standards and effective verification and accounting practices);[31] (5) an equitable transition to net zero (acknowledging common but differentiated responsibilities and respective capacities (CBDR-RC));[32] (6) alignment with socio-ecological objectives (net-zero plans should be integrated into broader strategies for protecting ecosystem services and socio-ecological sustainability);[33] and (7) interim milestones and implementation measures (detailed plans, including monitoring measures to review progress and revise as needed).[34]

Notwithstanding the findings of this growing area of research, defining the scope, timing, and equity of entity-level — as opposed to the overarching and singularly important global carbon-budget target — has fallen to individual GHG emitters and self-regulated voluntary codes (*e.g.,* the Crypto Climate Accord, discussed below).[35]

This raises serious questions about the efficacy and ethics of net zero as a frame for climate policy action. Some climate scientists, albeit still a minority, characterize net zero as a dangerous distraction and trap.[36] Net zero can perpetuate an uncritical and unrealistic faith in technological and market-based solutions.[37] Net zero can also diminish the sense of urgency around the need to

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Nonstate Actors in Global Climate Governance" in Kathleen Claussen, Charles-Emmanuel Cote, Atsuko Kanehara & Karen Scott, eds, *Changing Actors in International Law* (Leiden/Boston: Brill/Nijhoff, 2021) 234.

28 *Ibid.* at 17. See also Joeri Rogelj et al, "Three ways to improve net-zero emissions targets" (2021) 591 Nature 365.

29 Fankhauser et al, *supra* note 21 at 17; Rogelj et al, *supra* note 28 at 366.

30 Fankhauser et al, *supra* note 21 at 17; Lucas Joppa et al, "Microsoft's million-tonne CO_2-removal purchase — lessons for net zero" (30 September 2021) 597 Nature 629 at 630, online: <www.nature.com/articles/d41586-021-02606-3>.

31 Fankhauser et al, *supra* note 21 at 18; Joppa et al, *supra* note 30 at 630-631.

32 Fankhauser at al, *supra* note 21 at 18-19; Rogelj et al, *supra* note 28 at 367-368.

33 Fankhauser at al, *supra* note 21 at 19; Joppa et al, *supra* note 30 at 632.

34 Rogelj et al, *supra* note 28 at 368.

35 Fankhauser at al, *supra* note 21 at 16.

36 See e.g. James Dyke, Robert Watson & Wolfgang Knorr, "Climate scientists: concept of net zero is a dangerous trap," *The Conversation* (22 April 2021), online: <theconversation.com/climate-scientists-concept-of-net-zero-is-a-dangerous-trap-157368>.

radically reduce emissions as close to zero as soon as possible and lends support to slower, incremental, and business-as-usual approaches that advantage incumbent, vested interests.[38] Net zero, therefore, must be understood not simply as a scientific imperative, but rather a rich socio-political interpretive issue requiring input from many disciplines, "from climate science, biology and geology to anthropology, law and economics."[39]

This also raises the larger question — and, potentially, a paradox more tangible and more difficult than Zeno's paradox of motion alluded to above — "of how a diverse set of voluntary [net-zero] pledges adds up to national targets and national targets add up to the global carbon budget."[40] The global net-zero target tied to the remaining global carbon budget associated with the Paris Agreement temperature limits is a *net*-zero-emissions target — not a *zero*-emissions target — because even after 2050 there will almost certainly still be residual unabated GHG emissions from agricultural production.[41] While such emissions, especially nitrous oxide and methane emissions, can be reduced, they cannot be entirely eliminated.[42] With a rising global population, even in the event of transformational changes in food distribution, dietary preferences, and equity in respect of present food production systems, and with continuing changes to the climatic system, including changing rainfall patterns and soil conditions, there will most likely be additional demand for fertilizer use to maintain crop yields.[43] This means that, either by 2050 or afterwards, zero global emissions will not be possible. This, in turn, means that remaining unabated emissions that are impossible to eliminate must somehow be removed from the atmosphere by either natural or technological means, or some combination of the two.[44] Hence, the *global* emissions target of *net*-zero by around 2050 and thereafter, whereby anthropogenic emissions to and from the atmosphere balance on aggregate.[45]

But this global net-zero target is different, both in degree and in kind, from the thousands and potentially millions of national, subnational, and nonstate entities' individual net-zero pledges insofar as those net-zero pledges target GHG

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37 *Ibid*.

38 *Ibid*.

39 Fankhauser et al, *supra* note 21 at 19. See e.g. Jason MacLean, "Transnational Corporations and Climate Governance: A Case Study of Amazon.com's Net-Zero Climate Pledge," (2022) 42:5 Dal LJ 469.

40 Fankhauser et al, *supra* note 21 at 16.

41 See e.g. Dan Calverley & Kevin Anderson, "Phaseout Pathways for Fossil Fuel Production within Paris-Compliant Carbon Budgets" (2022) Tyndall Production Phaseout Report for the International Institute for Sustainable Development at 23 — 24, online: <www.iisd.org/publications/report/phaseout-pathways-fossil-fuel-production-within-paris-compliant-carbon-budgets>.

42 Fankhauser at al, *supra* note 21 at 23.

43 *Ibid*. at 23.

44 *Ibid*. at 23-24.

45 Fankhauser et al, *supra* note 21 at 540.

emissions that are neither essential (*i.e.,* arising from food production and distribution) nor impossible to eliminate.[46] Given the constraints on the feasible level of overall global emissions removals and storage, including high costs, technological incapacity, geopolitical uncertainty, and natural biological and geological limitations, net-zero models and policy pathways should seek to minimize the level of residual GHG emissions that must be removed from the atmosphere in order to achieve an aggregate balance. Yet this priority is seriously jeopardized — if not rendered completely out of reach — by the proliferation of sub-global pledges that seek to offset and outsource emissions reductions to others, including not only those essential emissions that are impossible to eliminate but also nonessential emissions that are merely costly, competitively disadvantageous, or inconvenient to eliminate. If the latter set of emissions exceeds the likely low level of emissions that we are able to remove from the atmosphere and store biologically and geologically, then who will eliminate these emissions, and not merely offset them?

Such is the paradoxical climate policy context in which crypto's climate problems must be assessed, to which this article now turns.

III. CRYPTO'S CLIMATE PROBLEM

Cryptocurrencies — particularly the leading currency, Bitcoin — pose several complex law and policy challenges. Arguably, the most pressing law and policy problem is their GHG emissions, especially their Scope 2 emissions, *i.e.,* the GHG emissions arising from the purchase of electricity to power their operations. Climate scientists measure and report GHG emissions by classifying them into three scopes.[47] Scope 1 emissions are the direct emissions resulting from an organization's activities. Scope 2 emissions are the indirect emissions from the production of the electricity an organization purchases and uses. Scope 3 emissions are all of the other indirect emissions resulting from an organization's activities, including the emissions embedded in an organization's supply chain, the complete life cycle of its products and services, the business travel of an organization's members, and the emissions stemming from the waste produced by an organization (see Fig. 1, *below*).[48]

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46 Here there are two further categories: (1) so-called "difficult-to-decarbonize" economic activities, including heavy-industry sectors such as steel and cement; and (2) all other emissions, be they expensive or otherwise disadvantageous or inconvenient to eliminate entirely. For an excellent discussion of the so-called "difficult-to-decarbonize" sectors of the economy that demystifies this putative difficulty and shows how decarbonization is possible, see Saul Griffith, *Electrify: An Optimist's Playbook for Our Clean Energy Future* (Cambridge, MA: The MIT Press, 2021) at 173-187.

47 *The Greenhouse Gas Protocol — A Corporate Accounting and Reporting Standard,* revised ed (Washington, DC: World Business Council on Sustainable Development & World Resources Institute, 2015).

48 *Ibid.*

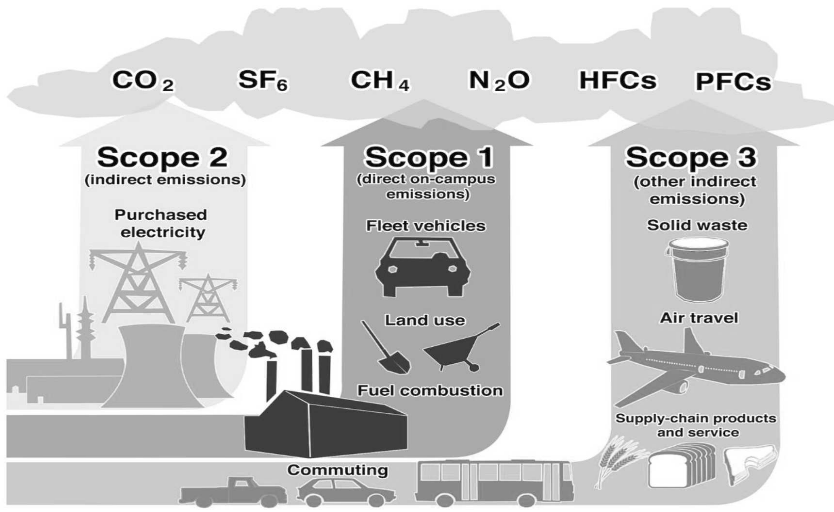

Fig. 1. Direct and indirect GHG emissions[49]

The process of "cryptomining" is the primary driver of extraordinarily high Scope 2 GHG emissions arising from cryptocurrencies; Bitcoin, the original and most popular cryptocurrency, accounts for approximately two-thirds of the total energy demand of all cryptocurrencies.[50] Cryptomining is the process whereby new "blocks" are added to a currency's extant distributed ledger (blockchain) of verified transactions. This computational process is a matter of trial and error in a numeric guessing game whereby a correct "guess" completes a new block, awarding the winner in this game newly minted crypto tokens and transaction fees.[51] Cryptocurrency software automatically adjusts the difficulty of guessing a correct number to maintain a constant time of 10 minutes between the creation of new blocks in a process that is technically referred to as "proof of work."[52] As of May 2021, nearly three million specialized computing machines competed in this "game," generating 160 *quintillion* guesses per second and consuming approximately 13 gigawatts (GW) of electricity.[53] Essentially, these computers are racing one another, and computing speed requires more and more energy.[54]

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49 Adapted from *ibid.*

50 Ulrich Gallersdörfer, Lena KlaaBen & Christian Stoll, "Energy Consumption of Cryptocurrencies Beyond Bitcoin" (2020) 4 Joule 1843.

51 Alex de Vries et al, "Revisiting Bitcoin's carbon footprint" (2022) 6 Joule 1 at 1.

52 *Ibid.*

53 *Ibid.* See also Alex de Vries & Christian Stoll, "Bitcoin's growing e-waste problem" (2021) Resources, Conservation & Recycling 175.

54 By contrast, the proof-of-stake system promised by Ethereum's long-awaited "Merge" requires far less energy. In a proof-of-stake framework, computers do not consume electricity by racing to verify transactions. Instead, Ethereum participants will deposit a

To appreciate crypto's growing carbon footprint, it is necessary to put this electricity use in context. In 2018, for example, global Bitcoin mining consumed *at least* 40 terra-watt hours (TWh), and perhaps as many as 62.3 TWh, of purchased electricity.[55] That is comparable to the amount of electricity purchased and consumed in Switzerland for the same year.[56] By 2021, this global estimate increased to 91 TWh, more electricity than Finland used that year.[57] In terms of Scope 2 GHG emissions, the latter figure translates to 65 megatons of carbon dioxide (CO_2) emissions, a figure comparable to the annual CO_2 emissions of Greece.[58] The carbon footprint of Ethereum, which is used to exchange the cryptocurrency Ether and which was also a proof-of-work blockchain prior to the "Merge" and its transformation into a proof-of-stake blockchain in September 2022, had been comparable to the annual GHG emissions of Finland.[59] The US Office of Science and Technology offers yet another series of comparisons of relative electricity use (see Fig. 2, *below*).

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certain number of digital coins into a shared pool, thus entering participants into a lottery whereby each time an exchange occurs, participants are selected to verify the transaction and earn currency rewards and transaction fees: Yaffe-Bellany, "What Is 'the Merge'?," *supra* note 10. That said, even the proof-of-stake framework will still require, just as the proof-of-work system requires, electricity for data storage, cooling, and data communications. See Office of Science and Technology Policy, *supra* note 9 at 13. Moreover, proof-of-stake systems will also produce downstream Scope 3 GHG emissions. It will be far from carbon-neural or free of environmental impacts.

55 David Yaffe-Bellany, "Bitcoin Miners Want to Recast Themselves as Eco-Friendly," *The New York Times* (22 March 2022), online: <www.nytimes.com/2022/03/22/technology/bitcoin-miners-environment-crypto.html>. See also de Vries et al, *supra* note 51.

56 Alex de Vries, "Renewable Energy Will Not Solve Bitcoin's Sustainability Problem" (2019) 3:4 Joule 893. See also the estimate provided in Spyros Foteinis, "Bitcoin's alarming footprint" (2018) 554 Nature 169.

57 Jon Huang, Claire O'Neill & Hiroko Tabuchi, "Bitcoin Uses More Electricity Than Many Countries. How Is That Possible?" *The New York Times* (3 September 2021), online: <www.nytimes.com/interactive/2021/09/03/climate/bitcoin-carbon-footprint-electricity.html>.

58 Yaffe-Bellany, "Crypto World Can't Wait," *supra* note 1.

59 Yaffe-Bellany, "What Is 'the Merge'?," *supra* note 10. As of this writing, Ethereum had just completed its transformation into a proof-of-stake blockchain (*i.e.,* "the Merge"). Further analysis and confirmation of this system's level of energy efficiency and other environmental impacts will no doubt be a priority for future research.

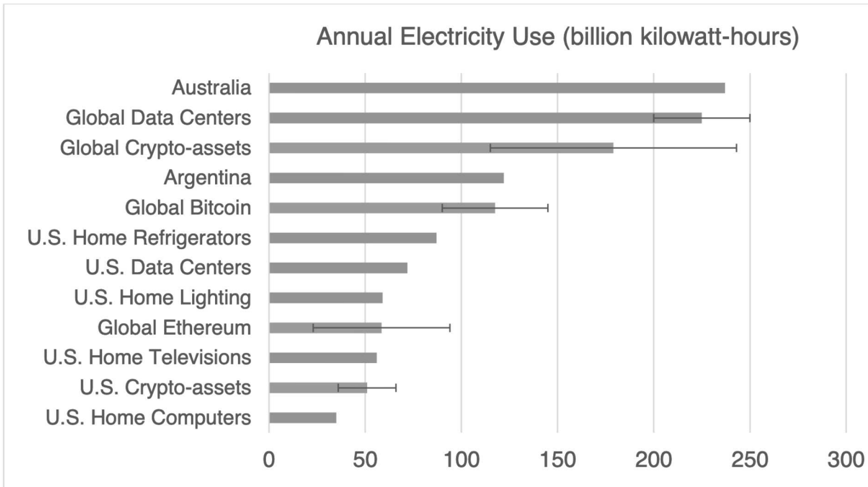

Figure 2. Annual electricity use of crypto-assets (as of August 2022)[60]

These estimates are all the more remarkable — and all the more concerning — given that the actual volume of cryptocurrency transactions remains, to date, quite limited. Over the course of 2019, for example, the Bitcoin network processed approximately 120 million transactions.[61] Traditional payment service providers, by contrast, processed approximately 539 *billion* transactions.[62] Nonetheless, one highly discussed study published in a leading climate change journal estimates that Bitcoin mining *in and of itself* could result in GHG emissions incompatible with the *global goal* of the Paris Agreement to limit global warming to well below 2 °C, not merely the net-zero target of the United States alone.[63]

Meanwhile, current estimates suggest that the global Bitcoin mining network's use of renewable energy declined from 42 percent in 2020 to 25 percent as of August 2021. This decline is likely due to a partial shift away from Bitcoin mining in China, where Bitcoin miners relied on heightened hydroelectricity supply during the summer months, toward Bitcoin mining powered by coal-generated electricity in parts of Mongolia, Kazakhstan, and the United States. Indeed, the United States now accounts for the world's largest share — approximately 38 percent — of Bitcoin mining.[64]

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60 Office of Science and Technology Policy, *supra* note 9 at 15.

61 Blockchain, "Confirmed Transactions Per Day" (2020), online: <www.blockchain.-com/charts/n-transactions>.

62 Capgemini, *World Payments Report* (2019), online: <worldpaymentsreport.com>.

63 Camilo Mora et al, "Bitcoin emissions alone could push global warming above 2 °C" (2018) 8 Nature Climate Change 931; Office of Science and Technology Policy, *supra* note 9 at 4.

More broadly, Bitcoin's growth in electricity usage can be illustrated by the following comparison (see Fig. 3, *below*): In 2009, you could mine a Bitcoin on a regular desktop or laptop computer; today, you need, at a minimum, a large room outfitted with highly specialized — and quickly obsolete and disposable — computing machines running 24-7.

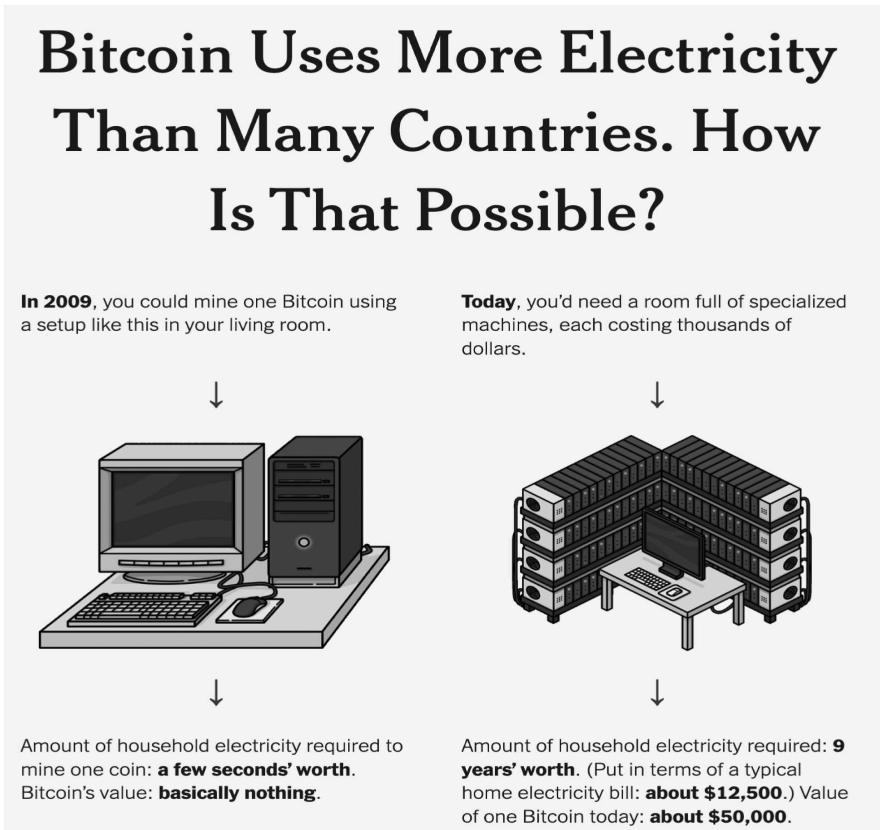

Fig 3. The growing energy demands of Bitcoin mining[65]

But Bitcoin's — and cryptocurrencies' — carbon footprint extends beyond significant Scope 2 GHG emissions. There is also a highly energy-intensive downstream (Scope 3) ecosystem of cryptocurrencies emerging and evolving now in real time (see Fig. 4, *below*). This energy-intensive ecosystem consists not only of "miners," but also exchange platforms, application providers, and crypto-asset holders. Yet this ecosystem's overall GHG emissions do not yet factor into

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[64] De Vries et al, *supra* note 51; Office of Science and Technology Policy, *supra* note 9 at 14.

[65] Huang, O'Neill & Tabuchi, *supra* note 57.

countries' emissions-reduction plans under the United Nations Paris Agreement on climate change.

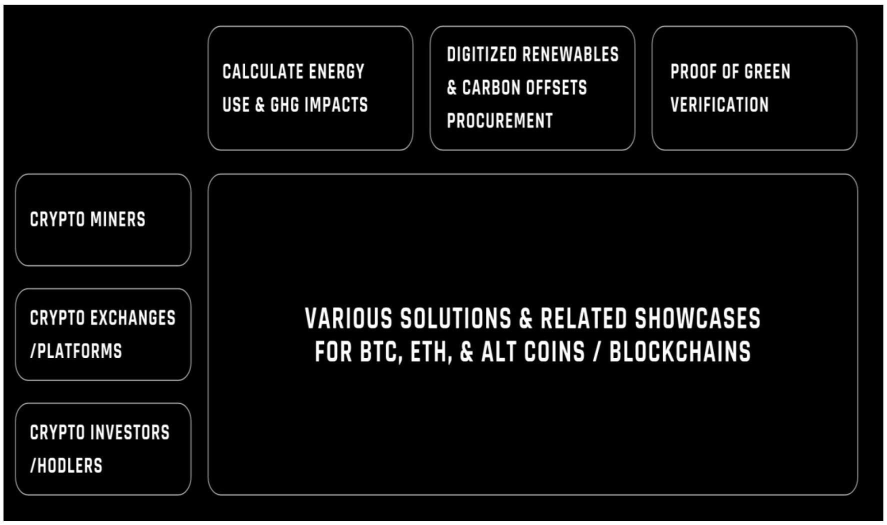

Figure 4. A "Green" Cryptocurrency Ecosystem?[66]

A Canadian example illustrates this broader emerging law and policy issue surrounding the growth of cryptocurrencies. In early 2022, Vancouver-based WonderFi Technologies Inc. set out to purchase the Toronto-based cryptocurrency trading platform Bitbuy Technologies Inc. after months of regulatory scrutiny that pushed provincial and territorial authorities across Canada to craft new policies around mergers and acquisitions in the digital asset and blockchain sector.[67] Operating under its parent company, First Ledger Corp., Bitbuy became the first regulated crypto marketplace in Canada when it received approval from the Ontario Securities Commission.[68]

As that regulatory process unfolded, however, the federal government was still in the process of issuing its first Emissions Reduction Plan under the *Canadian Net Zero Emissions Accountability Act* that the government enacted in 2021.[69] The Emissions Reduction Plan's purpose is to explain how Canada will meet its 2030 emissions-reduction target — a reduction of 40-45 percent of GHG

66 See the Crypto Climate Accord, online: <cryptoclimate.org/solutions/>.

67 Temur Durrani, "Kevin O'Leary-backed WonderFi closes deal to buy crypto exchange Bitbuy after long regulatory hurdles," *The Globe and Mail* (18 April 2022), online: <www.theglobeandmail.com/business/article-wonderfi-bitbuy-crypto-deal-kevin-oleary/>.

68 *Ibid.*

69 *Canadian Net Zero Accountability Act,* SC 2021, c 22.

emissions relative to the baseline year of 2005 — as well as reach "net-zero" GHG emissions by 2050. Yet Canada's first Emissions Reduction Plan, which purports to be "a comprehensive roadmap that reflects levels of ambition to guide emissions reduction efforts in each sector,"[70] does not acknowledge, much less address, the reduction of electricity use and GHG emissions arising from cryptocurrency transactions.[71]

This does mean, however, that cryptocurrency transactions are not presently being powered and processed in Canada. While comprehensive data are not available, a complicating law and policy problem in itself,[72] there are documented cases. For example, in July 2021, the Black Rock Petroleum Company announced the deployment of up to 1 million Bitcoin mining machines on gas-producing sites in Alberta.[73]

This is a typical arrangement. Cryptomining outfits are often located near existing power sources because of their heavy demand for electricity. This increase in power demand has already been associated with helping revive what would otherwise be retired and thus stranded fossil fuel assets (*i.e.,* assets that can no longer generate an economic return on investment). In New York State, for instance, stranded fossil fuel assets have been reactivated to power Bitcoin mining operations, and environmental advocates have warned that 30 fossil-fueled power plants in New York State could be reopened to power Bitcoin mining operations.[74] As another example, Kentucky has granted tax breaks to attract Bitcoin miners in order to support flagging coal companies and create additional economic opportunities.[75]

Accordingly, cryptocurrencies' growing climate problem is not solely a problem for the emerging crypto- and blockchain industry. Rather, it is a new

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70 Government of Canada, *2030 Emissions Reduction Plan: Canada's Next Steps for Clean Air and a Strong Economy* (Ottawa: 2022) at 7, online (pdf): <publications.gc.ca/collections/collection_2022/eccc/En4-460-2022-eng.pdf>.

71 *Ibid.*

72 This is also a growing problem in the United States. In a letter to the US Environmental Protection Agency (EPA), Senator Elizabeth Warren and other Democrats called for companies to report their GHG emissions, explaining that "little is known about the full scope of cryptomining activity." See Hiroko Tabuchi, "Cryptomining Capacity in U.S. Rivals Energy Use of Houston, Findings Show," *The New York Times* (15 July 2022), online: <www.nytimes.com/2022/07/15/climate/cryptocurrency-bitcoin-mining-electricity.html>. See also Office of Science and Technology Policy, *supra* note 9 at 8.

73 de Vries et al, *supra* note 51 at 3. In 2019, the province of Quebec limited the energy available to cryptominers to 688 megawatts.

74 Michael Hall, "Bitcoin-mining power plant raises ire of environmentalists," *Associated Press* (16 October 2021), online: <abcnews.go.com/US/wireStory/bitcoin-mining-power-plant-raises-ire-environmentalists-80618790>.

75 John Cheves, "KY lawmakers want tax breaks for cryptocurrency mining. But will this create jobs?" *Media Mentions, Kentucky.com* (4 March 2021), online: <www.blockwaresolutions.com/media-mentions/ky-lawmakers-want-tax-breaks-for-cryptocurrency-mining-but-will-this-create-jobs>.

and significant dimension to the global challenge to reach net-zero GHG emissions by 2050 in order to limit global temperature rise to well below 2 °C per the Paris Agreement. As the world continues to struggle mightily even to initially embark on a policy pathway toward net-zero emissions (which is discussed further in the next part of this article), this new economic sector is adding the equivalent of another developed country's amount of annual GHG emissions to a shrinking global carbon budget.[76]

It is crucial to add that cryptocurrencies' climate problem is not one that can be simply eliminated by cryptominers and exchanges switching from fossil-fuel energy sources to renewable energy sources. Using renewable energy to power cryptomining and exchanges, which, under current practices, require continuous energy use at every time of the day, every day of the year, will compete with renewable energy and grid baseload capacities for heating and cooling buildings and homes, producing food, and moving people around. Even a renewable-energy-based crypto ecosystem will pose significant energy security and energy justice issues.[77] Indeed, following China's cryptomining ban, cryptomining operations moved to other countries that not only have coal-powered electricity but also *less available spare renewable energy capacity*.[78] In 2021, the Swedish Financial Supervisory Authority and Environmental Protection Agency called for a ban on cryptocurrency mining over concerns that the use of renewable energy for cryptomining could delay the energy transition for Sweden's essential services.[79] More recently, the US White House Office of Science and Technology Policy cautioned that "rapidly growing new power demand must avoid unmanageable impacts to the grid and use the most efficient technology available. It is also crucial that electricity remains affordable for homes and businesses."[80] Such calls are likely to grow more frequent in the future.

Nor can renewable energy, if and when such a shift in crypto's energy generation were to occur, effectively address the enormous amount of electronic waste (e-waste) produced by the high turnover of specialized, single-use computers. Like its GHG emissions, the crypto industry's e-waste profile is growing and is already comparable to that of a small country.[81] On one recent estimate, the shelf-life of a specialized single-use computer for Bitcoin mining is 1.5 years for even the most "efficient" Bitcoin mining operations.[82] E-waste is a

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76 IPCC, *supra* note 20 at 38.

77 See generally Joeri Rogelj et al, "Three ways to improve net-zero emissions targets" (2021) 591:7850 Nature 365 at 367-368; Dominic Lenzi et al, "Equity implications of net zero visions" (2021) 169:20 Climatic Change.

78 Tabuchi, *supra* note 4.

79 Finansinspektionen, "Crypto-assets are a threat to the climate transition — energy-intensive mining should be banned" (2021), online: <www.fi.se/en/published/presentations/2021/crypto-assets-are-a-threat-to-the-climate-transition–energy-intensive-mining-should-be-banned/>.

80 Office of Science and Technology Policy, *supra* note 9 at 5.

81 de Vries, *supra* note 51; Huang, O'Neill & Tabuchi, *supra* note 57.

serious environmental problem that includes contamination from toxic chemicals and heavy metals leaching into soils along with air and water pollution from improper recycling.[83] Cryptomining operations also cause local noise and water impacts, as well as air pollution, each of which can "exacerbate environmental justice issues for underserved communities."[84]

IV. CRYPTO'S CLIMATE PARADOXES

Because cryptocurrencies are currently a regulatory blind spot, as they are neither acknowledged nor addressed in countries' Paris Agreement commitments, the leading approach to decarbonizing the industry is the "Crypto Climate Accord," a voluntary, private-sector-led initiative inspired by the Paris Agreement encompassing the entire crypto ecosystem and blockchain industry.[85] Signatories to the Crypto Climate Accord pledge to reach net-zero GHG emissions by 2040. They further pledge to (1) achieve net-zero Scope 2 GHG emissions from purchased electricity by 2030, and (2) develop standards, tools, and technologies to facilitate and verify progress toward 100-percent-renewably-powered blockchains by the 2025 United Nations Framework Convention on Climate Change's (UNFCCC) thirtieth conference of the parties (or COP30; COP27 was held during the fall of 2022)..[86]

The Crypto Climate Accord envisages a series of self-regulatory options to reduce industry emissions, including (1) achieving greater energy efficiency by optimizing infrastructure and sourcing more energy-efficient hardware; (2) "load shifting," or altering the timing of electricity use to off-peak times; (3) relocating mining operations to draw energy from different grids; (4) investing in on-site renewable energy sources (*e.g.,* on-site solar PV); (5) procuring unbundled energy attribute certificates (EACs) to combine with the use of fossil-fueled "brown" power; and (6) purchasing off-site renewable energy (*e.g.,* direct or virtual power purchase agreements, or PPAs).[87] Of these, the latter two options — purchasing energy certificates and agreements, effectively seeking to offset GHG emissions — figure most prominently in the Crypto Climate Accord's decarbonization strategy. As the Accord's technical accounting and reporting guidance explains,

> Even after implementing one or more strategies to decarbonize emissions — including the Scope 2 emissions that are the focus of this guidance document — some emissions footprint may remain. In

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[82] de Vries, *supra* note 56.

[83] de Vries & Stoll, *supra* note 53.

[84] Office of Science and Technology Policy, *supra* note 9 at 6.

[85] Crypto Climate Accord, *supra* note 66.

[86] *Ibid.*

[87] Marc Johnson & Sahithi Pingali, "Guidance for Accounting and Reporting Electricity Use and Carbon Emissions from Cryptocurrency — Produced to Advance the Crypto Climate Accord" (15 December 2021) at 27, online (pdf): <cryptoclimate.org/wp-content/uploads/2021/12/RMI-CIP-CCA-Guidance-Documentation-Dec15.pdf>.

> such cases, actors targeting net-zero emissions can further look to carbon offsets as a way to mitigate the remaining carbon footprint. This is consistent with the approach leading tech companies and other corporations are taking today with their sustainability strategies: invest in energy efficiency and renewable energy first, to reduce their emissions footprint, then invest in carbon offsets to zero-out any remaining balance.[88]

The trouble with this strategy is that, like leading tech companies and other corporations, the crypto industry's investments in energy efficiency and on-site renewable energy appear to be declining, or not increasing at the same rate as the operational growth in their carbon footprints.[89] Moreover, like other tech operations and corporations, downstream — Scope 3 — GHG emissions are also a significant decarbonization obstacle, making offsets an even more important part of net-zero commitments. Here again the Accord's technical guidance offers a telling explanation:

> Since downstream users' emissions from the *use* of cryptocurrency are indirect emissions, reaching net zero emissions as a user [or a miner, or an exchange] of cryptocurrency will require the purchase of mitigation credits [offsets]. One incentive mechanism that offers a holder the possibility to offset their emissions is the solution the CCA [Crypto Climate Accord] community is currently developing with industry stakeholders to 'tokenize' EACs [energy attribute certificates], such as RECs [renewable energy certificates], GOs [guarantee of origin], and I-RECs [international renewable energy certificates]. This open-source technical architecture will create tokenized pools for crypto miners, exchanges, and investors to procure high-quality EACs, carbon offsets, and carbon removal from verified providers.[90]

The Crypto Climate Accord's emphasis and reliance on offsetting its GHG emissions illustrates the paradoxical nature of the industry's climate problem, and of net zero more generally. Thus a closer look at the Accord's preferred offsetting mechanisms is warranted.

(a) Offsetting Cryptomining's Carbon Emissions

Renewable Energy Certificates (RECs) are used in several jurisdictions and go by different names, including Energy Attribute Certificates (EACs) and Guarantees of Origin (GOs). They are available for purchase in several forms, including: (1) unbundled RECs, which are purchased from a third party separately from the supplier of the procured energy; (2) bundled RECs, *third*-

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88 *Ibid.* at 28.

89 de Vries et al, *supra* note 51 at 2, 4, observing that the "decreasing usage of renewable electricity sources for Bitcoin mining following the crackdown in China highlights the need for stakeholders in the crypto industry to accelerate efforts to decarbonize the industry."

90 Johnson & Pingali, *supra* note 87 at 29.

party-generated, whereby energy suppliers procure RECs from a third party to bundle those RECs with energy sales as a "green" premium product (in such cases the energy supplier may well be delivering fossil-fuel-powered energy while the third party that provides the RECs is producing renewable energy); and (3) bundled RECs, *supplier-generated*, whereby energy suppliers with their own renewable energy generation sell their own RECs bundled with other energy sales.[91]

Crucially, however, the sale of RECs does not necessarily contribute to *additional* renewable energy supply capacity.[92] At best, the purchase of RECs signals to investors that there is a growing demand for renewable energy, and this signal will contribute to the generation of additional aggregate renewable energy in the long term. However, there is yet no empirical evidence of this indirect signaling effect.[93] In fact, the evidence suggests that the opposite is true, on account of the oversupply of certificates and resulting lower prices, and the implicit double counting of claimed emissions reductions.[94]

There is, for example, an oversupply in Europe of RECs at low prices largely resulting from decades-old hydroelectricity power stations throughout Scandinavia that have been in operation since long before the advent of RECs.[95] RECs have thus had no appreciable influence on renewable power generation in those countries, where there is little incentive to purchase RECs given the widespread perception that the countries' energy system is already largely renewable.[96] Consequently, RECs based on Scandinavian hydropower tend to be sold to countries outside the region, resulting in implicit double counting of renewable energy generation and offsetting of carbon emissions.[97] Suppose a German cryptominer that produces Scope 1 GHG emissions and also consumes predominantly fossil-fueled electricity from the German electricity grid — yielding Scope 2 emissions — purchases a Norwegian REC and then claims lower Scope 1 and Scope 2 emissions on the basis of that purchased REC. Neither the German grid nor the Norwegian hydropower station owner has any incentive to increase its respective renewable energy generation as a result of this transaction, so actual GHG emissions remain unchanged and unmitigated.[98] Of

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91 Thomas Day et al, "Corporate Climate Responsibility Monitor 2022: Assessing the Transparency and Integrity of Companies' Emission Reduction and Net-Zero Targets" (Berlin: New Climate Institute, February 2022) at 32, online: <https://newclimate.org/wp-content/uploads/2022/02/CorporateClimateResponsibilityMonitor2022.pdf>

92 *Ibid*. See also Anders Bjørn et al, "Renewable energy certificates threaten the integrity of corporate science-based targets" (2022) 12 Nature Climate Change 539.

93 Bjørn et al, *supra* note 92 at 539.

94 Day et al, *supra* note 91 at 32.

95 *Ibid*. at 32. Note that the same can be said for much of Canada, especially British Columbia, Manitoba, and Quebec.

96 *Ibid*. at 32.

97 *Ibid*..

98 *Ibid*.

course, exceptions undoubtedly obtain. Yet what this example illustrates is not only the risk that RECs will not increase renewable energy capacity, including the relative share of renewable energy in the overall energy mix, but also the difficulty of reliably determining the actual environmental impact of purchasing an REC in the first place.[99]

RECs can also displace carbon-intensive energy to other entities without changing the overall energy mix. Imagine an electricity grid that receives electricity generated from both fossil fuels and renewable energy, a commonplace scenario. The consumers of electricity from this typical grid all receive a combination of the two energy sources, and thus all of their carbon footprints include Scope 2 emissions. Now imagine that one customer, a Bitcoin mining facility, buys an REC from the owner of a wind-power facility that feeds the electricity grid. The Bitcoin miner will use the REC to offset, partially or fully, its Scope 2 emissions. But in reality, the Bitcoin miner still receives electricity produced by both fossil fuels and renewable energy, as will all other customers of the grid, including those that have not purchased RECs. Those non-purchasers of RECs, however, will *appear* to have relatively higher Scope 2 emissions than the Bitcoin miner that purchased the REC. Once again, the REC transaction does not necessarily — or even probably — increase the generation of renewable energy.[100] Even where it does so in the aggregate, it may still fail to displace any fossil-fueled electricity. Instead, the increased renewable energy supply may simply be used to meet higher overall aggregate energy demand, and in doing so will not contribute to decarbonization or net zero.

These risks, it turns out, are real, not merely speculative. A recent empirical examination of corporations' use of RECs to report reduced Scope 2 emissions demonstrates that the widespread use of RECs has led to an inflated estimate of the effectiveness of corporations' mitigation efforts.[101] Researchers combined climate change disclosure data from 115 companies based mostly in Europe and the United States with data on those companies' REC purchases to assess the effects of RECs on the alignment between companies' reported Scope 2 emissions and the Paris Agreement's temperature targets over the period 2015-2019.[102] The sample of companies reported a combined 30.7 percent reduction in annual Scope 2 emissions over the study period; however, the researchers found that most of this reported reduction in emissions was caused by the companies' use of RECs in their market-based emissions reporting, which increased from covering 8 percent of their purchased energy in 2015 to 27 percent in 2019, not by any real location-based emissions reductions.[103] Over the same period, actual location-based emissions were reduced by only 10.3 percent annually, rather than by 30.7

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99 *Ibid.*

100 *Ibid.*

101 Bjørn et al, *supra* note 92 at 539.

102 *Ibid.*

103 *Ibid.* at 539-541.

percent as claimed by companies' reports.[104] Moreover, this lower actual reduction was not primarily due to the companies' decarbonization efforts, but rather to the independent decarbonization of electricity grids.[105] Purchasing RECs allows corporations "to report emissions reductions that are not real."[106]

More broadly, corporations' — including crypto-industry players' — growing use of RECs as emissions offsets casts serious doubt on both the veracity and the efficacy of their net-zero pledges and other so-called science-based climate targets. As the study's authors further observe, when the corporations' emissions reductions based on purchased RECs are removed from the sample analysis, the corporations' combined 2015-2019 Scope 2 emissions-reduction trajectories are not aligned with the 1.5 °C pathway under the Paris Agreement and are only barely aligned with the well-below 2 °C pathway.[107] If this trend continues, and the researchers' study finds that most corporations in the sample intend to continue to use RECs to meet their emissions targets, as much as 42 percent of committed Scope 2 emissions reductions will not result in any real-world mitigation.[108]

Thus we arrive back where we started, with the ostensible paradox of net-zero emissions pledges that only nominally offset emissions by outsourcing to others the challenging task of making real emissions reductions. What emerges is a kind of shell game aptly described by the climate activist Greta Thunberg as "creative carbon accounting."[109] Crypto is neither alone nor extraordinary as an example of an industry and a broader ecosystem of economic activity seeking to offset and outsource its climate responsibility to others.[110] But crypto's climate

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104 *Ibid*. at 541.

105 *Ibid*. In fairness, it should be noted that the researchers did not estimate the potential indirect effect of REC purchases on grid demand and mix. Such a signal may have such an effect over the long term, despite the lack of evidence to date. This makes the presence of a short-term signal all the more unlikely. Nonetheless, it should be estimated in future studies.

106 *Ibid*. at 543.

107 *Ibid*. at 539.

108 *Ibid* at 539, 542. This startling figure is likely conservative, given that RECs and a wide variety of other offset products are used to report reductions of not only Scope 2 emissions, but Scope 1 and Scope 3 emissions as well.

109 Greta Thunberg, "There are no real climate leaders yet — who will step up at Cop26?" *The Guardian* (21 October 2021), online: < www.theguardian.com/commentisfree/2021/oct/21/climate-leaders-cop26-uk-climate-crisis-glasgow >.

110 The Crypto Climate Accord does, however, seek to extend this process a step further by seeking to tokenize offsets and deliver verification by using public blockchains. The Accord's carbon and accounting reporting guidance explains this proposal in the following terms: "This solution will offer a new digitized option for any crypto market participant to cover its respective energy use or carbon emissions associated with the energy use of their crypto holdings/activity" (Johnson & Pingali, *supra* note 87 at 29). Of course, this very use of blockchain to verify credit for emissions reductions will in itself entail energy and environmental impacts that must also, in a net-zero world, be offset, creating a kind of *reductio ad infinitum* — and perhaps also a *reductio ad absurdum* —

impacts and net-zero strategy do bring into clear relief not only the limitations of net zero as a climate law and policy framework, but also what should be a growing chorus of nagging doubts about the presumptive complementarity of climate protection and economic growth (*e.g.,* sustainable development).[111] This article concludes below by briefly unpacking this uncritical presumption and its implications for net-zero law and policy scholarship.

CONCLUSION: Not-so-Nagging Doubts About Continuous Economic Growth

Crypto's advocates appear not to share these concerns, and, in some cases, they seek to minimize the industry's climate impact through a series of arguments: (1) the mainstream financial system also uses a significant amount of energy, from powering millions of bank branches, including A.T.M.'s that remain idle most of the time, to mining for gold, to powering energy-intensive infrastructure; (2) many cryptomining computers are powered by renewable energy or by fossil-fueled energy that would otherwise go to waste; and (3) newer blockchains are being built using the more energy-efficient consensus-based proof-of-stake verification framework.[112]

These objections, however, are largely inaccurate and misleading. As already discussed above, crypto's use of renewable energy appears to be declining, not increasing, and cryptomining's use of fossil-fuel-based energy is reviving fossil-fuel assets — including coal-fired power plants and natural gas plants — that would otherwise be retired, thereby slowing the renewable energy transition.

As for the consummation of the long-awaited "Merge," not only will it not displace Bitcoin mining, and not only will it face opposition from incumbent Ethereum proof-of-work miners,[113] but it will also not necessarily guarantee an

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recursion of offsets and blockchain uses, again not unlike Zeno's ancient paradox of motion. On a less philosophical note, the US White House Office of Science and Technology Policy helpfully observes that "the potential use cases for blockchain in carbon markets track existing market functions, and their adoption will depend on whether blockchain can offer an improvement over existing technologies in cost, speed, and security, *without causing additional environmental harms*": Office of Science and Technology Policy, *supra* note 9 at 28 [emphasis added].

111 Jonas Meckling & Bentley B Allan, "The evolution of ideas in global climate policy" (2020) 10 Nature Climate Change 434 at 437. See also David Marchese, "This Pioneering Economist Says Our Obsession With Growth Must End," *The New York Times* (17 July 2022), online: <www.nytimes.com/interactive/2022/07/18/magazine/herman-daly-interview.html>.

112 Roose, *supra* note 5.

113 On one estimate, Ethereum mining operations have an aggregate of $US 5 billion invested in energy-intensive proof-of-work computational hardware: "The future of crypto is at stake in Ethereum's switch," *The Economist* (6 September 2022), online: <www.economist.com/finance-and-economics/2022/09/06/the-future-of-crypto-is-at-stake-in-ethereums-switch>. Incumbent proof-of-work miners may well attempt to maintain a proof-of-work version of Ethereum, ultimately resulting not in a successful

environmental-impact-free cryptocurrency ecosystem. As a recent analysis of proof-of-stake's energy footprint concludes, "other networks employing different consensus mechanisms as well as second layer networks need to be taken into account to gain a holistic picture of the environmental impact of cryptocurrencies and tokens."[114] And this is to say nothing of proof-of-stake's downstream Scope 3 GHG emissions.

But perhaps most importantly, there is presently no evidence to suggest that the crypto-industry is capable of *replacing* the mainstream financial services industry. At most, crypto is an *alternative* to mainstream finance, and, as such, it represents *additional* economic activity and, along with it, additional climatic and environmental impacts.[115] This, in turn, raises the question of the presumed complementarity of perpetual economic growth and environmental protection.

In 2001, for example, the Organisation for Economic Cooperation and Development (OECD) cautioned that future advances in resource efficiency would be counteracted by increases in consumption.[116] Since then, scientific concepts such as the Anthropocene, planetary boundaries and tipping points,[117] and degrowth[118] have revived concerns first expressed in the late 1960s and early 1970s about environmental limits to economic growth.[119] Despite these longstanding scientific concerns, in policy discourse on both net-zero emissions in general and cryptocurrencies as one of many specific examples, "the discourse on limits to growth appears as the nagging doubt underneath the dominant notion of the complementarity of climate protection and economic growth."[120]

Regrettably, this otherwise accurate summation of the evolution of climate-policy thinking since the early 1990s[121] actually overstates the influence of limits-

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"Merge" but rather in a "Fork." This too will have to be factored into future estimates of crypto-assets' climate and environmental impacts.

114 Ulrich Gallersdörfer, Lena KlaaBen & Christian Stoll, "Energy Efficiency and Carbon Footprint of Proof of Stake Blockchain Protocols" (Crypto Carbon Ratings Institute: January 2022) at 24, online (pdf): <file:///Users/jasonmaclean/Downloads/CCRI-PoS-Report-2022.pdf>. Further note that this analysis does not include proof-of-stake's Scope 3 GHG emissions, either, which ought to further temper the optimism surrounding "the Merge."

115 This raises an interesting question in itself: to the extent that some crypto advocates argue that the benefits of decentralization justify crypto's climate and environmental costs (see Roose, *supra* note 5), what can be made of this cost-benefit calculus if blockchains become more centralized, that is, if consensus-based blockchain protocols take hold and are controlled primarily by a concentrated economic and technical (*i.e.,* coder) elite?

116 *Annual Report of 2001* (Paris: OECD, 2001).

117 See e.g. David I Armstrong McKay et al, "Exceeding 1.5°C global warming could trigger multiple climate tipping points" (2022) 377 Science eabn7950.

118 See e.g. Lorenz T KeyBer & Manfred Lenzen, "1.5 °C degrowth scenarios suggest the need for new mitigation pathways" (2021) 12 Nature Communications 2676.

119 The *locus classicus* is Donna Meadows et al, *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind* (Universe Books, 1972).

120 Meckling & Allan, *supra* note 111 at 437.

to-growth concerns in climate policy discourse. After all, a "nagging doubt" is a doubt that nags and distracts and, in so doing, causes uncertainty and worry.[122] There is little evidence, however, of any "nagging doubt" underlying the global concept of net zero or its specific applications, including in the cryptocurrency industry; in both contexts, "win-win" outcomes are the presumed products of a coming green economic transformation.[123]

Would that it were true! In this brief study of the crypto- and blockchain industry's climate and environmental impacts in the broader global context of net-zero climate pledges, I have sought to suggest that matters may not be so simple and convenient. We may have to make hard choices to avert climate catastrophe and environmental destruction. We may not be able to have both nonfungible tokens *and* trees.

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[121] *Ibid.*

[122] I am grateful to my colleague Jim Robson at the University of Saskatchewan's School of Environment and Sustainability for putting a fine point on the misapplication of "nagging doubt" in this context.

[123] A growing number — albeit still very much a minority — of climate academics are beginning to sound the alarm about ongoing climate-policy inaction and the "cascading and catastrophic consequences this implies": Stuart Capstick et al, "Civil disobedience by scientists helps press for urgent climate action" (2022) Nature Climate Change, <www.nature.com/articles/s41558-022-01461-y>.