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OUT WITH THE OLD, IN THE NEW: OPPORTUNITIES FOR BLOCKCHAIN TO ENHANCE TRANSPARENCY UNDER THE PARIS AGREEMENT

LAWS 523: Special Topic: International Climate Change Law

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Abstract

The international climate change regime is exemplified by three key instruments: the United Nations Framework Convention on Climate Change, the Kyoto Protocol, and the Paris Agreement. Traditionally, international law has sought to address climate change through top-down solutions by settling multilaterally agreed emission reduction targets on developed countries. However, this approach proved increasingly controversial over time. Consequently, there has been a paradigm shift towards a more flexible, bottom-up approach, under which states determine their own contributions towards reducing global temperatures. This approach was most recently incorporated in the Paris Agreement, which relies on transparency, rather than sanctions, to promote ambition. This new approach in international climate change law intersects with the emergence of Blockchain technology; a digital ledger which is increasingly touted as a potential solution to the climate crisis. This paper will examine how blockchain could be utilised to implement two core objectives of the Paris Agreement; climate change mitigation and the provision of climate finance, both of which can be undermined by a lack of transparency. This paper suggests that while blockchain does provide exciting opportunities to enhance transparency under the Paris Agreement, it is not a panacea to the climate crisis, and there are various challenges that need to be overcome before blockchain opportunities can be fully realised.

Word Count

The text of this paper (excluding the table of contents, abstract, footnotes, and bibliography) comprises approximately 11,500 words.

Key Words

The Paris Agreement; blockchain technology; climate change; climate finance; carbon markets; Nationally Determined Contributions; transparency; international climate change law.

Every paradigm shift starts with terminology of which many make use yet only a few can make sense…. Climate change… is an example of a term constantly undergoing this process of redefinition. Edging up the modern lexicon to meet it is "blockchain"...[1]

I Introduction

The world is in a state of climate emergency. The Intergovernmental Panel on Climate Change (IPCC) has found that human activities, in particular the release of greenhouse gases (GHGs), has unequivocally caused the climate to change.[2] While the precise effects of the Anthropocene remain uncertain, there is no doubt that climate change will have profound consequences for the environment, economy, and human health.[3] Predictions suggest that there is a risk of irreversible damage if temperatures increase to 1.5 degrees Celsius above pre-industrial levels.[4] Considering temperatures have already risen by approximately one-degree Celsius, urgent action is needed to prevent a catastrophic temperature increase.[5]

Despite these stark warnings, international law has struggled to effectively address the climate change challenge. Climate change has been aptly described as a "complex, polycentric, and seemingly intractable policy challenge".[6] The complexity of the issue is difficult to overstate; the impacts of climate change are global, transcending state boundaries and generations.[7] Consequently, effective climate action requires states with competing interests to act towards a common goal, which will come at a significant economic cost.[8] Climate change also raises difficult ethical questions; developing countries often view international climate politics as part

[1] Alastair Marke (ed) *Transforming Climate Finance and Green Investment with Blockchains* (1st ed, eBook ed, Academic Press, 2018) at 15.
[2] Intergovernmental Panel on Climate Change Working Group I *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Intergovernmental Panel on Climate Change Sixth Assessment Report, 2021) at [3.8.1].
[3] David Hunter, James Salzman and Durwood Zaekle *International Environmental Law and Policy* (5th ed, Foundation Press, New York, 2015) at 6.
[4] Lenton TM and others "Climate Tipping Points - Too Risky to Bet Against" (2019) 575 Nature 592 at 592.
[5] Temperatures have increased by one degree Celsius compared to pre-industrial levels. See Intergovernmental Panel on Climate Change *Special Report: Global Warming of 1.5 Degrees Celsius* (Summary for Policymakers, 2018) at 4.
[6] Daniel Bodansky, Jutta Brunnée, and Lavanya Rajamani *International Climate Change Law* (Oxford University Press, Oxford, 2017), at 209.
[7] At 2.
[8] At 3.

of a larger pattern of historical injustices and therefore assert that industrialised countries should bear the primary burden of combating climate change.[9]

These factors combine to create a "super wicked problem".[10] Traditionally, international law has sought to address climate change through top-down solutions that impose multilaterally agreed, legally binding, emission reduction targets on Parties. This approach was first introduced in the United Nations Framework Convention on Climate Change (UNFCCC), and subsequently adopted by the Kyoto Protocol.[11] These top-down emission reduction targets were expected to help build trust between states by deterring non-compliance and free-riding.[12]

In order to attract participation from developing states, the UNFCCC and Kyoto Protocol both limited emission reduction targets to developed states. These differentiated responsibilities reflected the historic, and present, contribution of GHG emissions by developed countries, as well as their access to technological and financial resources.[13] However, this proved increasingly controversial over time. Consequently, there has been a paradigm shift towards a more flexible, bottom-up, approach under which states determine their own contributions towards reducing global temperatures. This approach was most recently incorporated in the Paris Agreement, which relies on transparency, rather than sanctions, to promote ambitious climate action.

By moving away from this top-down approach, the Paris Agreement eliminated the "firewall" between developed and developing countries, and avoided the distributional conflict inherent in negotiating top-down mitigation targets.[14] This reduced the sovereignty costs of a legally binding instrument, and ultimately resulted in broad participation from both developed and developing states.[15]

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[9] At 9.
[10] Richard J. Lazarus "Super Wicked Problems and Climate Change: Restraining the Present to Liberate the Future" (2009) 94 Cornell L Rev 1153 at 1159.
[11] Robert Falkner "The Paris Agreement and the New Logic of International Climate Politics" (2016) 92 International Affairs 1107 at 1110.
[12] At 1110. For more information on the rationale behind a top-down approach, see William Hare and others "The Architecture of the Global Climate Regime: a Top-down Perspective" (2011) 10 Climate Policy 600 at 601.
[13] Ellen Hey *Advanced Introduction to International Environmental Law* (Edward Elgar Publishing Limited, Cheltenham, 2016) at [4.5.7].
[14] Daniel Bodansky "The Paris Climate Change Agreement: A New Hope?" (2016) 110 AJIL 288 at 298.
[15] Lavanya Rajamani "Understanding the 2015 Paris Agreement" in *India in a Warming World: Integrating Climate Change and Development* (Oxford University Press, Delhi, 2019) 205 at 210.

This paradigm shift in international climate change law intersects with the emergence of blockchain technology; a digital ledger which is increasingly touted as a potential solution to the climate crisis.[16] The UNFCCC suggests that blockchain could "boost" climate action peer-to-peer renewable energy trading, improved carbon emission trading, enhanced climate finance flows, and better tracking of GHG emissions to monitor implementation of NDCs.[17]
This paper focuses on two core objectives of the Paris Agreement where a blockchain application could prove the most beneficial: climate change mitigation and the provision of climate finance.[18]

This paper begins by examining the developments in the international climate change regime that led to the eventual adoption of the Paris Agreement, before discussing the key provisions of the Agreement itself. Chapter IV will provide a brief introduction to blockchain technology; this will provide the background for the subsequent examination of how blockchain could be used to implement the Paris Agreement mitigation and financing goals. Finally, Chapter VI considers the technical and political challenges associated with the use of this nascent technology.

Ultimately, this paper will conclude that while there is potential for blockchain to enhance climate finance flows, improve carbon emission trading, and enable better tracking of GHG emissions, this new technology cannot overcome the political challenges inherent in international climate change law.

II Paving the Way: the UNFCCC, Kyoto and Copenhagen

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[16] See for example, Guillaume Chapron "The Environment Needs Crypto-Governance" (2017) 545 Nature 403; Alastair Marke (ed) *Transforming Climate Finance and Green Investment with Blockchains* (1st ed, eBook ed, Academic Press, 2018); Climate Ledger Initiative *Navigating Blockchain and Climate Action: An Overview* (December 2018); UNFCCC "How Blockchain Technology Could Boost Climate Action" (01 June 2017) <www.UNFCCC.com>.

[17] UNFCCC "How Blockchain Technology Could Boost Climate Action" (01 June 2017) <www.UNFCCC.com>. For information on how blockchain could be used in peer-to-peer renewable energy trading, f, see Manish Kumar Thukral "Emergence of Blockchain Technology Application in Peer-to-peer Electrical Energy Trading: a Review" (2021) 5 Clean Energy 104; and Alastair Marke (ed) *Transforming Climate Finance and Green Investment with Blockchains*, above n, ch 5-9.

[18] Climate change adaptation is outside the scope of this paper.

The United Nations climate change regime has developed through three phases.[19] The first phase is exemplified by the UNFCCC, the second by the Kyoto Protocol, and the third by the "global approach" first enounced in the Copenhagen Accord and subsequently adopted in the Paris Agreement.[20]

The Paris Agreement builds upon lessons learned from the UNFCCC and Kyoto. Therefore, any assessment of the Paris Agreement must first consider its predecessors. Accordingly, the following section will introduce the UNFCCC, Kyoto Protocol, and the Copenhagen Accord, all of which were instrumental in what would later be agreed on in Paris.

A The United Nations Framework Convention on Climate Change

The UNFCCC is the "foundation of the United Nations climate regime", and both the Kyoto Protocol and Paris Agreement were both established "under its auspices".[21] The UNFCCC was the first international environmental agreement to recognise climate change as a global issue. The main objective of the UNFCCC, and any subsequent legal instrument, is to stabilise GHG concentrations in the atmosphere at a level that would prevent dangerous interference with the climate system.[22]

Notably, the Convention provided the climate change regime's initial approach to differentiation through the annex structure, which broadly classified Parties as developed (Annex-I) or developing (non-Annex-I) and assigned obligations accordingly.[23] Under art 4.1, all Parties were required to, *inter alia*, establish, and communicate national programmes to mitigate climate change. Comparatively, Annex-I Parties had more defined obligations to return their emissions to 1990 levels by 2000.[24] Furthermore, developed states listed in Annex-II, a subset of Annex-I, were required to provide financial and technological resources to developing countries.[25]

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[19] Bodansky "The Paris Climate Change Agreement: A New Hope?", above n 14, at 291.
[20] At 291.
[21] Daniel Bodansky, Jutta Brunnée, and Lavanya Rajamani *International Climate Change Law* (Oxford University Press, Oxford, 2017), at 118.
[22] United Nations Framework Convention on Climate Change 1771 UNTS 101 (opened for signature 16 March 1982, entered into force 21 March 1994), art 2.
[23] Article 4.
[24] Article 4.2
[25] Article 4.

While the UNFCCC was relatively vague, it is only a framework convention, therefore, it was always contemplated that Parties would establish more detailed targets.[26] Accordingly, both the Kyoto Protocol and Paris Agreement were intended to operationalise the vague principles set out in the UNFCCC.[27]

B The Kyoto Protocol

The second phase of the United Nations climate change regime began in 1995, when negotiations for the Kyoto Protocol began. The Kyoto Protocol has been described as one of the most "complex and ambitious environmental agreements ever negotiated".[28] The Protocol maintained the annex structure of the UNFCCC by committing developed countries to legally binding, multilaterally agreed, emission reduction targets.[29] Annex-I Parties were required to ensure that their total GHG emissions did not exceed their assigned level of emissions over the commitment period.[30]

While the international climate change regime would later depart from this top-down approach, the Kyoto Protocol nevertheless provided key lessons that would be influential in the Paris Agreement. Most importantly, the Kyoto Protocol "catalysed a vibrant carbon market" that will likely "leave an enduring imprint on the climate regime".[31] The Protocol enabled Annex-I Parties to add to or subtract from their initial assigned amount by trading emission units with other Parties using the so-called Kyoto mechanisms; joint implementation, the Clean Development Mechanism (CDM) and emissions trading.[32] Joint implementation and CDM operate similarly; both allow developed countries to offset their emissions by investing in emission reduction projects in another country.[33] The difference is that a CDM activity occurs in a developed

[26] Article 17.
[27] Bodansky, Brunnée and Rajamani *International Climate Change Law*, above n 20, at 119.
[28] At 161.
[29] At 166-167.
[30] The Kyoto Protocol to the United Nations Framework Convention on Climate Change 2303 UNTS 214 (opened for signature 16 March 1998, entered into force 16 February 2005), art 3.1.
[31] Bodansky, Brunnée and Rajamani *International Climate Change Law*, above n 20, at 203.
[32] Andrei Marcu *Governance of Article 6 of the Paris Agreement and Lessons Learned from the Kyoto Protocol* (Centre for International Governance Innovation, Fixing Climate Governance Series Paper No. 4, May 2017) at 2. These mechanisms are defined in the Kyoto Protocol to the United Nations Framework Convention on Climate Change, above n 29, arts 6, 12 and 17.
[33] See Bodansky, Brunnée and Rajamani *International Climate Change Law*, above n 20, at 180-184.

country, whereas joint implementation occurs in another developed country.[34] Furthermore, developed countries could fulfil their Kyoto targets by trading the following: excess emission units (emissions that are "allowed" but not used), a removal unit, a certified emission reduction (generated by the CDM), or an emission reduction unit (generated by a joint implementation project).[35] These mechanisms allowed Annex-I Parties to "take advantage of lower-cost emission reductions outside their territories".[36]

Under the centralised approach of the Kyoto Protocol, rigorous monitoring, verification and reporting was seen as necessary to uphold the integrity of the market mechanisms.[37] To be eligible to participate in these mechanisms, Annex-I Parties were required to meet specific reporting requirements.[38] Under art 5, each Annex-I Party was required to establish and maintain a national system to estimate the anthropogenic emissions and removals according to specified methodologies accepted by the IPCC and agreed upon by the Conference of the Parties. The national monitoring system was intended to facilitate Annex-I countries in preparing an annual inventory of greenhouse gas emissions and removals as required under art 7, and ultimately support developed country Parties in complying with art 3.[39]

To facilitate communication between different carbon market registries, the Kyoto Protocol utilised an International Transaction Log, which had a "mandate to carry out the centralized function, including a clearance process for transactions" and was overseen by the UNFCCC.[40] While largely successful, this approach has been criticised as being expensive and overly rigid.

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[34] The Kyoto Protocol to the United Nations Framework Convention on Climate Change, above n 29, art 17. See also Igor Shishlov, Romain Morel and Valentin Bellassen "Compliance of the Parties to the Kyoto Protocol in the First Commitment Period" (2016) 16 Climate Policy 768 at 775.

[35] See Bodansky, Brunnée and Rajamani *International Climate Change Law*, above n 20, at 180.

[36] United Nations Framework Convention on Climate Change *Kyoto Protocol Reference Manual on Accounting of Emissions and Assigned Amount* (2018), at 15.

[37] Bodansky, Brunnée and Rajamani *International Climate Change Law,* above n 20, at 193.

[38] The Kyoto Protocol to the United Nations Framework Convention on Climate Change, above n 29, arts 5.1, 5.2, 7.1 and 7.1. See also United Nations Framework Convention on Climate Change *Kyoto Protocol Reference Manual on Accounting of Emissions and Assigned Amount*, above n 35, at 15.

[39] Bodansky, Brunnée and Rajamani *International Climate Change Law,* above n 20, at 194; and United Nations Framework Convention on Climate Change *Kyoto Protocol Reference Manual on Accounting of Emissions and Assigned Amount*, above n 35, at 15.

[40] Shishlov, Morel and Bellassen, above n 33, at 775.

Overall, the Kyoto Protocol generated "valuable experience" on well-functioning carbon markets, including "national inventories, a common accounting system, common time frames and uniform reporting formats".[41] However, the Protocol's ambitious, top-down, approach came at a cost. The Kyoto Protocol took eight years to come into force without the support of the United States of America (the United States), who refused to ratify the Protocol, and negotiations for the second commitment period took an additional seven years. One commentator suggests that Kyoto "sought to do too much too quickly… in advance of the requisite political will to maintain the regime".[42]

One of the key issues with the Protocol was the sharp differentiation between developed and developing Parties, which became increasingly contentious over time.[43] This tension was especially apparent during negotiations for the second commitment period; developing countries wanted to maintain the differentiated approach, whereas developed countries were reluctant to bind themselves to strict targets, particularly considering China, the United States, and other major economies, were not.[44] Consequently, Canada withdrew, while Japan and Russia stated they would not be bound by new targets.[45] Kyoto's coverage was now limited to approximately fifteen percent of global emissions.[46]

Kyoto's first commitment period was set to end in 2012. Therefore, in 2005 Parties began to discuss what to do post-2012. These discussions culminated in the 2009 Copenhagen Conference.

C Copenhagen: a new approach

The 2009 Copenhagen conference was expected to result in a successor agreement to the Kyoto Protocol.[47] However, this conference suffered from a "severe dichotomy of interests,"[48] and the resulting document, the Copenhagen Accord, was a "poor political compromise...rather than a

[41] Bodansky, Brunnée and Rajamani *International Climate Change Law*, above n 20, at 207.
[42] At 207.
[43] At 166.
[44] At 292.
[45] Falkner, above n 11, at 1111.
[46] Bodansky "The Paris Climate Change Agreement: A New Hope?", above n 14, at 301.
[47] Ulrich Beyerlin and Thilo Marauhn *International Environmental Law* (Hart Publishing, Oxford, 2011) at 168,
[48] At 168.

fully-fledged legally binding international agreement".[49] This was a blow to the United Nations climate change regime, with one commentator concluding that "multilateral climate diplomacy had reached a dead end".[50]

However, despite being considered a "disaster" the Copenhagen Accord laid the foundations for much of what was eventually implemented in the Paris Agreement.[51] The Accord abandoned the differentiated annex structure of UNFCCC and Kyoto Protocol in favour of a more flexible approach, under which parties determined their own emission reduction measures.[52] This attracted much broader participation than Kyoto, and for the first-time emerging economies established emission reduction pledges.[53]

However, an issue with the bottom-up approach in Copenhagen was that the national commitments lacked transparency, and were therefore difficult to understand, which made progress difficult to measure.[54] This made it impossible to hold states accountable for their pledges and would prove influential in what was subsequently agreed on in Pairs.[55]

III The Paris Agreement

Paris is a treaty, therefore, while certain provisions articulate non-binding obligations, the overall instrument is binding on the 190 parties who have adopted it.[56]

Prior to Paris, negotiations had focused on a "fruitless" effort to establish a global emission target, which only exacerbated tensions between states.[57] Despite the apparent end of climate diplomacy, the Paris Agreement emerged "like a phoenix from the ashes" to provide renewed optimism for the international climate change regime.[58] Paris sought a "solution that is neither

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[49] At 169.
[50] Faulkner, above n 11, at 1107.
[51] Navroz K. Dubash and Lavanya Rajamani "Beyond Copenhagen: next steps" (2011) 10 Climate Policy 593 at 593.
[52] Bodansky "The Paris Climate Change Agreement: A New Hope?", above n 14, at 300.
[53] At 301.
[54] At 301.
[55] At 301.
[56] At 296.
[57] Falkner, above n 2 at 1124.
[58] Bodansky "The Paris Climate Change Agreement: A New Hope?", above n 14, at 296.

too strong (and hence unacceptable to key states) nor too weak (and hence ineffective)".[59] By moving away from the traditional top-down approach, Paris eliminated the sharp divide between developed and developing countries, representing a major advance in the international climate change regime.[60]

A Climate change mitigation

The Paris Agreement aims to limit global warming "to well below two degrees Celsius above pre-industrial levels".[61] Article 2.1(a) adds that states should pursue "efforts to limit the temperature increase to 1.5 degrees Celsius above pre-industrial levels", acknowledging that this would "significantly reduce the risks and impacts of climate change".[62] This mitigation objective aligns with current scientific understanding; the IPCC reported in 2019 that limiting global warming to 1.5 degrees Celsius would significantly reduce the risk of heavy precipitation events, extreme drought, floods, species, and ecosystem loss, as well as water and food scarcity.[63] While the 1.5 degrees Celsius goal may be more "aspirational" than realistic, it "nevertheless… sets a direction of travel for the climate regime" and signals solidarity with vulnerable states who will bear the brunt of climate impacts.[64]

1 Nationally Determined Contributions

The UNFCCC notes that "mitigation lies at the heart of Parties' efforts to achieve the… long-term temperature goals".[65] In order to realise the long-term temperature goal, set out in art 2.1(a), the Paris Agreement utilises NDCs. NDCs are pledges by Parties which outline the mitigation actions they are taking to achieve the temperature goal.[66] States are required to submit NDCs every five years, and it is expected that each one is more ambitious than the last.[67] To ensure countries are on track to meet the temperature goal, a "global stocktake" will occur every

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[59] At 289.
[60] At 298.
[61] The Paris Agreement (opened for signature 22 April 2016, entered into force 4 November 2016), art 2(a).
[62] Article 2.1(a).
[63] Intergovernmental Panel on Climate Change *Global Warming of 1.5°C* (Special Report, 2019), at ch 3.
[64] Bodansky, Brunnée and Rajamani *International Climate Change Law*, above n 20, at 299.
[65] UNFCCC "Mitigation in the negotiations" <www.unfccc.com>.
[66] United Nations Environment Programme *Emissions Gap Report 2020* UN Doc DEW/2310/NA (09 December 2020) at x.
[67] The Paris Agreement, above n 59, art 4.

five years.[68] The global stocktake will assess Parties' progress towards the temperature goal, the result of which shall inform subsequent NDCs, ideally promoting greater ambition.[69]

During negotiations, there was general agreement that procedural commitments to communicate NDCs should be included, however, the legal status of NDCs was more controversial.[70] Some states suggested that making NDCs legally binding would give them greater credibility.[71] However, other states argued that a strong transparency framework could promote ambition and compliance without compromising broad participation.[72] Daniel Bodansky notes that "legal bindingness can be a double-edged sword, if it leads States not to participate or to make less ambitious commitments".[73] It was ultimately decided that parties would have procedural obligations to prepare, communicate and maintain successive NDCs.[74] However, given the resistance to top-down targets, particularly from the US, India, and China, it was agreed that parties would not be bound to implement their nationally determined pledges.[75] In other words, it is an "obligation of conduct rather than an obligation of result".[76]

This approach represents a significant departure from the top-down approach to mitigation provisions in the UNFCCC and Kyoto Protocol, which created a rigid dichotomy between developed and developing countries. While the mitigation obligations under the UNFCCC were broad, both UNFCCC and Kyoto Protocol included substantive legal obligations for Annex-I countries to reduce emissions.[77] Neither agreement contained any binding emission reduction obligations for developing countries.

[68] Article 14.
[69] Article 14. See also Marjan Peeters "Article 14: the Global Stocktake" in Leonie Reins and Geert van Calster (eds) *The Paris Agreement on Climate Change: A Commentary* (Edward Elgar Publishing Limited, Cheltenham, 2021) 326 at 327.
[70] Bodansky "The Paris Climate Change Agreement: A New Hope?", above n 14, at 304.
[71] At 297.
[72] At 297.
[73] Daniel Bodansky "The Legal Character of the Paris Agreement" (2016) 2 RECIEL 142 at 150.
[74] The Paris Agreement, above n 59, art 4.2.
[75] Bodansky "The Paris Climate Change Agreement: A New Hope?", above n 14, at 304.
[76] At 304.
[77] United Nations Framework Convention on Climate Change, above n 21, art 4; and the Kyoto Protocol to the United Nations Framework Convention on Climate Change, above n 29, art 3.1.

Comparatively, the Paris Agreement commits all parties, regardless of their level of development, to submit NDCs, in which they self-select the climate actions they are willing to take.[78] Countries are not legally bound to meet the substantive commitments pledged in their NDCs; if parties do not meet their nationally determined targets, they will not have violated a legal obligation.[79] This avoided the distributional conflict that was "inherent" in the Kyoto Protocol negotiations, and as a result near universal participation was achieved, with 191 Parties adopting the Agreement.[80]

However, because NDCs are voluntary, and the compliance mechanism is "expert-based and facilitative… in a manner that is transparent, non-adversarial and non-punitive", the Paris Agreement relies on transparency to hold states accountable.[81]

2 Carbon markets

Climate change mitigation under art 4 is supplemented by the carbon market provisions in art 6. Cost-effective mitigation of GHG emissions will be crucial for achieving the temperature goal agreed to in the Paris Agreement.[82] Carbon markets, which place a price on emissions, are widely considered to be an economical way to reduce GHG emissions.[83] The rationale behind such schemes is that emission reductions have the same effect regardless of where they occur, and therefore reductions should be made where it is most cost-effective to do so.[84] As of 2021, there were 64 carbon pricing instruments in operation, and another three scheduled to be implemented.[85] This accounts for 21.5 percent of global GHG emissions, an increase from 15.1 percent in 2020.[86]

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[78] The Paris Agreement, above n 59, art 4.2.
[79] Patrícia Galvão Ferreira *Climate Finance and Transparency in the Paris Agreement: Key Current and Emerging Legal Issues* (Center for International Governance Innovation Papers No. 195, October 2018) at 2.
[80] Faulkner, above n 11, at 1107.
[81] At 1121.
[82] Marco Schletz, Laura A. Franke and Søren Salomo, "Blockchain Application for the Paris Agreement Carbon Market Mechanism—A Decision Framework and Architecture" (2020) 12 Sustainabilty 1 at 1.
[83] Marissa Santikarn and others *A Guide to Linking Emissions Trading Systems* (International Carbon Action Partnership, 2018) at 9.
[84] Carbon Market Solutions "History of Emissions Trading" <www.carbonmarketsolutions.com>.
[85] The World Bank *State and Trends of Carbon Pricing 2021* (2021), at 21.
[86] At 21

If carbon markets are well designed, they have the potential to increase the mitigation ambition, which is particularly important if the temperature goal set out in art 2 is going to be achieved.[87] Therefore, despite some opposition to market-based approach during Paris negotiations, art 6.1 recognises that Parties, in implementing their NDCs, may choose to pursue voluntary cooperation "to allow for higher ambition in their mitigation and adaptation actions and to promote sustainable development and environmental integrity".[88] More than half the intended NDCs submitted contemplated the use of carbon markets, which suggested there is "broad support for inclusion of a market-based provision".[89] While art 6 does not explicitly refer to "markets", it effectively provides for two market mechanisms; first, parties may engage in "cooperative approaches" (essentially emissions trading) under art 6.2, while art 6.4 establishes a "centrally governed crediting mechanism", similar to the CDM.[90] However, the focus of this essay will be on art 6.2.[91]

Article 6.2 states that Parties can, on a voluntary basis, enter into "cooperative approaches that involve the use of internationally transferred mitigation outcomes (ITMOs)" to achieve their NDCs.[92] In contrast to the Kyoto Protocol, which relied on comprehensive rules and centralised accounting, art 6.2 of the Paris Agreement instead establishes a decentralised approach which requires Parties to unilaterally ensure "environmental integrity and transparency", and "apply robust accounting to ensure, inter alia, the avoidance of double counting". This aligns with the bottom-up nature of the Paris Agreement, which places heavy reliance on strong transparency provisions to track climate action.

B Climate finance

[87] Matthieu Wemaërein "Article 6: Voluntary Cooperation/NDCs" in Leonie Reins and Geert van Calster (eds) The Paris Agreement on Climate Change: A Commentary (Edward Elgar Publishing Limited, Cheltenham, 2021) 148 at 150.
[88] Bodansky, above n 11, at 307.
[89] At 307.
[90] At 307.
[91] This paper focuses on art 6.2 because the decentralised nature of this market mechanism has the greatest potential for a blockchain application.
[92] The Paris Agreement, above n 59, art 6(2).

The Paris Agreement recognises that structural transformation of the global economy is needed to effectively address climate change.[93] This is reflected in art 2.1(c), which states that one of the key objectives of the Agreement is to make finance flows consistent with a pathway towards low GHG emissions and climate-resilient development. To achieve this objective, increased mobilisation of climate finance will be needed. This is addressed in art 9 of the Agreement.

Climate finance generally refers to "all finance flows aimed at reducing emissions, enhancing carbon sinks, as well as reducing vulnerability and supporting resilience to the adverse effects of climate change".[94] It is estimated that developing countries alone will require 500 billion dollars each year by 2030 for mitigation, and an additional several hundred billion for climate change adaptation.[95] While the provision of climate finance has increased over the years, it continues to fall short of what is required.[96]

Traditionally, developed countries have faced unilateral climate finance obligations, which reflects their greater financial means, and historic responsibility for GHG emissions.[97] However, prior to Paris, some developed country Parties suggested that the distinction between developed and advanced developing countries had become increasingly blurred, and thus should be reconsidered.[98] However, this was met with resistance from developing countries, especially China.[99] The Paris Agreement therefore affirms that developed country Parties have an obligation to provide financial resources to developing country Parties.[100] The preservation of this distinction has been described as the "core of the compromise that enabled broad global consensus toward the Paris Agreement", as developing countries would only agree to undertake significant climate actions if developed countries were required to provide climate finance.[101]

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[93] Halldór Thorgeirsson "Objective (Article 2.1)" in Daniel Klein and others (eds) *The Paris Agreement on Climate Change: Analysis and Commentary* (Oxford University Press, Oxford, 2017) 123 at 128.
[94] UNFCCC Standing Committee on Finance *2014 Biennial Assessment and Overview of Climate Finance Flows* (2014) at 5.
[95]Alastair Marke and Bianca Sylvester "Decoding the Current Global Climate Finance Architecture" in Alastair Marke (ed) *Transforming Climate Finance and Green Investment with Blockchains* (1st ed, eBook ed, Academic Press, 2018) 35 at 37. All figures are presented in USD.
[96] Michael Mehling "Article 9: Finance" in Leonie Reins and Geert van Calster (eds) The Paris Agreement on Climate Change: A Commentary (Edward Elgar Publishing Limited, Cheltenham, 2021) 218 at 220.
[97] At 225.
[98] At 225.
[99] At 226.
[100] The Paris Agreement, above n 59, art 9.1.
[101] Ferreira, above n 77, at 2.

However, other Parties are encouraged to provide or continue to provide financial support voluntarily.[102] While this is weaker than what developed countries had sought, it "signals the desirability of support from developing countries", and in doing so "softens the traditional divide between donor and recipient countries".[103]

However, art 9.3 requires developed countries to "take the lead in mobilising climate finance from a wide variety of sources, instruments and channels, noting the significant role of public funds". This provision acknowledges that increasing climate finance to the necessary levels will require mobilisation from a range of sources, including domestic and international sources, as well as private funds.

Furthermore, art 9.3 of the Agreement states that mobilisation of climate finance should represent "a progression beyond previous efforts". During the 2009 Copenhagen Accord, developed countries agreed to jointly mobilise 100 billion dollars a year by 2020, which was formalised by the following year in the Cancún Agreements.[104] While the text of the Paris Agreement does not explicitly provide developed countries with a concrete funding commitment or goal, this provision indicates that developed countries must not only deliver on the 100 billion dollar pledge, but that this should be seen as a floor, not a ceiling.[105] This is supplemented by the "quantified and firm" financial commitment established during the twenty-first session of the Conference of the Parties, which extended the collective mobilisation goal of 100-billion-dollars per year to 2025 and asks that a new collective goal be set before 2025.[106]

Again, transparency is of central importance; one of the biggest issues in the context of climate finance is a "lack of transparency to recipient communities… and trust among stakeholders".[107] This results in "unnecessary barriers in raising funds plus delays in approving and implementing climate change projects urgently needed in the most vulnerable countries".[108]

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[102] The Paris Agreement, above n 59, art 9.2.
[103] Mehling, above n 95, at 226.
[104] At 223.
[105] At 227.
[106] At 227; UNFCCC *Adoption of the Paris Agreement* (Decision 1/CP.21) at [53].
[107] Alastair Marke and Bianca Sylvester "Decoding the Current Global Climate Finance Architecture" in Alastair Marke (ed) *Transforming Climate Finance and Green Investment with Blockchains* (1st ed, eBook ed, Academic Press, 2018) 35 at 35.
[108] Marke and Sylvester, above n 22, at 35.

Overall, an effective climate finance regime relies heavily on adequate transparency. Transparency enables improved understanding of the amount and characteristics of climate finance flows, and how mobilisation could be optimised.[109] Transparent monitoring, reporting, and verification (MRV) of climate finance can also generate trust between developed and developing countries.[110] Therefore, art 9.5 requires developed countries to biennially communicate indicative information on the future provision of climate finance to developing countries, while art 9.7 requires developed countries to report financial support provided to developing countries.

C Transparency framework

Transparency has been described as an "indispensable backbone" of the international climate change regime.[111] The success of the bottom-up pledge and review approach in the Paris Agreement largely depends on the efficacy of the so-called "enhanced transparency framework", which aims to "to build mutual trust and confidence and to promote effective implementation".[112]

In contrast to the UNFCCC and Kyoto Protocol, the Paris Agreement's transparency framework on climate action applies, in principle, to all Parties. Developed and developing countries must provide information on their emissions by establishing national greenhouse gas inventories, as well as the necessary information to track progress made towards their NDCs.[113] However, the transparency framework does provide for "built-in flexibility", taking into account developing countries' different capacities.[114] Article 13.3 further suggests that the transparency framework will be implemented "in a facilitative, non-intrusive, non-punitive manner, respectful of national sovereignty, and avoid placing undue burden on Parties".

While the transparency framework for action applies to both developed and developing countries alike, albeit with built-in flexibility, the transparency framework for support is only mandatory

[109] Climate Ledger Initiative *Navigating Blockchain and Climate Action: An Overview*, above n 16, at 40.
[110] Yulia Yamineva "Climate Finance in the Paris Outcome: Why Do Today What You Can Put Off Till Tomorrow?" (2016) 25 RECIEL 174 at 182.
[111] Harro van Asselt and Kati Kulovesi "Article 13: Enhanced Transparency Framework for Action and Support" in Leonie Reins and Geert van Calster (eds) *The Paris Agreement on Climate Change: A Commentary* (Edward Elgar Publishing Limited, Cheltenham, 2021) 302 at 304.
[112] The Paris Agreement, above n 59, art 13.1.
[113] Article 13.
[114] Article 13.1.

for developed country parties.[115] Article 13.9 states that "developed country Parties shall provide information on financial, technological transfer and capacity-building support provided to developing country Parties". Comparatively, other Parties that provide support only "should" supply such information.[116] Furthermore, there is no mandatory requirement for developing countries to provide information on support required or received.[117] Developed countries' commitment to provide financial support to developing countries was central to the compromise that led to broad participation in the Paris Agreement.[118] Transparent reporting of climate finance will be essential to maintain trust between Parties, and give developing nations confidence to undertake more ambitious mitigation targets".[119]

The rationale behind the enhanced transparency framework is that, by making information on Parties' emissions and climate policies transparent, this will provide confidence that Parties are working towards implementing their NDCs, and are providing the necessary financial and technological support.[120] This in-turn will increase the likelihood of reciprocal action by other Parties.[121] Moreover, the transparency framework is expected to generate pressure on Parties domestically and internationally, which will incentivise countries to increase the ambition of their NDCs.[122] At the domestic level, NDCs "have an important signalling effect to domestic constituencies, indicating a government's green credentials at home and environmental leadership internationally".[123] Governments will be subject to scrutiny by the media, public, environmental groups, as well as transnational non-governmental organisations.[124] Furthermore, where international pledges are incorporated into domestic legislation, they will be subject to scrutiny through parliaments and courts.[125] Overall, civil society can be expected to monitor,

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[115] Ferreira, above n 77, at 2.
[116] The Paris Agreement, above n 59, art 13.1.
[117] Article 13.10.
[118] Ferreira, above n 77, at 1.
[119] Romain Weikmans, Harro van Asselt and J. Timmons Roberts "Transparency requirements under the Paris Agreement and their (un)likely impact on strengthening the ambition of nationally determined contributions (NDCs)" (2020) 20 Climate Policy 511 at 513.
[120] Asselt and Kulovesi "Article 13: Enhanced Transparency Framework for Action and Support," above n 107, at 304.
[121] At 304.
[122] Faulkner, above n 11, at 1121-1122.
[123] At 1122.
[124] At 1122.
[125] At 1122.

albeit informally, the climate agreement, using naming and shaming tactics to target free-riders.[126]

Peer pressure can also occur at the international level. Ian Johnstone argues that "states care about collective judgment of their conduct because they have an interest in reciprocal compliance by and future cooperation with others".[127] Transparency as to how a Party has implemented its NDC "could highlight… that it needs to, or could, do more to avoid reputational costs.[128] Robert Falkner suggests that, ideally, leaders in climate action will use the transparency mechanism to signal high ambition, while laggards to increase their commitments, in the hope that this "will create a positive spiral of strengthening trust and enhanced cooperation".[129]

D The Paris Agreement: a reason for hope?

Relying on transparency to promote ambition, rather than sanctions, is controversial; some commentators argue that a top-down regime is the most effective option, because "only a strong and effective top-down regime" can deter non-compliance and free riding.[130] While an ideal system would see states agree to mandatory and ambitious mitigation targets, this is not realistic in the current international climate regime, where states prioritise sovereignty and are hesitant to bind themselves to enforceable commitments. Dudash and Rajamani acknowledge that:[131]

> It is doubtful whether an ideal top-down climate regime with adequate commitments and strong compliance procedures can be negotiated in the time-scale required to meaningfully address climate change.

The Kyoto Protocol attempted to operationalise top-down architecture by setting mandatory emission reduction targets. However, to ensure support of developing countries, these targets could only apply to developed countries. This differentiation, while necessary, created significant

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[126]At 1123.
[127] Ian Johnstone "The power of interpretative communities" in Michael Barnett and Raymond Duvall (eds) *Power in Global Governance* (Cambridge: Cambridge University Press, 2005) 185 at 187.
[128] Weikmans, van Asselt and Roberts "Transparency requirements under the Paris Agreement and their (un)likely impact on strengthening the ambition of nationally determined contributions (NDCs)", above n 115, at 513.
[129] Faulkner, above n 11, at 1121.
[130] Hare and others, above n 12, at 603-604.
[131] Navroz K. Dubash and Lavanya Rajamani "Beyond Copenhagen: next steps" (2011) 10 Climate Policy 593 at 595.

tension between developed and developing countries, and international cooperation became strained.

Paris accepts the current reality of international law, and rather than attempting to negotiate top-down targets, it allows states to determine their own action through NDCs. This success of climate diplomacy justifies cautious optimism on the future of the international climate change regime.

IV Blockchain: a New Paradigm

The bottom-up nature of the Paris Agreement represents a paradigm shift in the international climate arena. This new approach intersects with the emergence of blockchain; a revolutionary technology that has the potential to facilitate implementation of the Paris Agreement.

However, before discussing how blockchain could be used to accelerate climate action under the Paris Agreement, the following section will provide a brief overview of how this revolutionary technology works and its key characteristics.[132]

A What is blockchain technology?

In 2008, Satoshi Nakamoto[133] released *Bitcoin: A Peer-to-Peer Electronic Cash System* which would provide the blueprint for the development of blockchain technology.[134] The most well-known application of Blockchain technology is Bitcoin; an electronic payment system that allows parties to transact with each other directly, removing the need for banks to become involved.[135] However, blockchain technology has already developed beyond cryptocurrency, and is now being hailed as the "Fourth Industrial Revolution"

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[132] The purpose of this section is to provide sufficient detail to understand how blockchain can be used to implement the Paris Agreement, however the complex technical details are outside the scope of this paper. For a more comprehensive analysis of how blockchain works, see Antony Welfare *Commercializing Blockchain: Strategic Applications in the Real World* (John Wiley & Sons Ltd, West Sussex, 2019); and Imran Bashir *Mastering Blockchain* (2nd edition, Packt Publishing, Birmingham, 2018).
[133] This is a pseudonym.
[134] Satoshi Nakamoto *Bitcoin: A Peer-to-Peer Electronic Cash System* (White Paper, 2008). For a history of blockchain see generally Melanie Swan *Blockchain: Blueprint for a New Economy* (1st ed, eBook ed, O'Reilly Media, Boston, 2015).
[135] Zibin Zheng and others "Blockchain challenges and opportunities: a survey" (2018) 14 IJWGS 352 at 354.

due to its potential to significantly disrupt the current “social, cultural, political and legal landscape”.[136]

Blockchain can be defined as:[137]

> …. a peer-to-peer, distributed ledger that is cryptographically secure, append-only, immutable…. and updateable only via consensus or agreement among peers.

Blockchain is a type of Distributed Ledger Technology.[138] This means that there is no central authority in the network, and all participants communicate directly.[139] This decentralized environment is possible by integrating several technologies,[140] all of which are discussed below.

Blockchain stores and transmits data in a growing list of packages known as “blocks”.[141] Each “block” contains the following: data, a “hash”, the hash of the previous block and a timestamp.[142] A hash is a unique code, effectively a “digital fingerprint”, that sets it apart from every other block.[143] These blocks are then “chained” together in chronological order, which helps prevent tampering; if a block is tampered with, the hash will change, this will invalidate all subsequent blocks, as they no longer contain a valid hash of the previous block.[144]

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[136] Vincent Mignon “Blockchains – perspectives and challenges” in Daniel Kraus, Thierry Obrist and Olivier Hari (eds) *Blockchains, Smart Contracts, Decentralised Autonomous Organisations and the Law* (Edward Elgar Publishing, Cheltenham, 2019) 1 at 6.
[137] Bashir, above n 130, at 16.
[138] This paper uses the word “blockchain” rather than “digital ledger technology” (DLT), although blockchain is only one application of DLT and not all distributed ledgers necessarily use blockchain technology. See Harish Natarajan, Solvej Krause and Helen Gradstein *Distributed Ledger Technology (DLT) and Blockchain* (World Bank FinTech Note No. 1, Washington DC, 2017) at VII. See also Amarpreet Singh “Distributed Ledger vs Blockchain Technology: Do You Know the Difference?” Medium <www.medium.com>.
[139] Bashir, above n 125, at 16.
[140] Zheng and others, above n 131, at 354.
[141] At 354.
[142] At 354.
[143] Climate Ledger Initiative *Blockchain Potentials and Limitations for Selected Climate Policy Instruments* (March 2019) at 19.
[144] Karsten Schulz and Marian Feist “Leveraging blockchain technology for innovative climate finance under the Green Climate Fund” (2021) 7 Earth System Governance 1 at 3.

B The consensus mechanism

Due to the decentralized nature of this technology, there is no single authority who can update the data on the blockchain, and a blockchain can only be updated where consensus is reached among all the nodes on the network.[145] A "node" is the server in which the blocks are stored on, and "can be any kind of device", such as computers or laptops.[146] All nodes on the blockchain are connected to one another, and when a new block is added to the chain, it is broadcast to the other nodes on the network.[147] In order for the new block to be added to the chain, the nodes must reach consensus as to the validity of the transaction, which will be executed only if all the nodes approve it.[148]

In a distributed system such as blockchain, reaching consensus among nodes is a realisation of the "Byzantine Generals Problem".[149] In this problem, a group of army generals circle a city; to proceed, all generals must come to a consensus to attack.[150] However, there may be traitors among the generals. In such a trustless environment, reaching consensus becomes difficult.[151] Similarly, the distributed nature of the blockchain network makes reaching consensus among untrusting nodes difficult.[152] Therefore, a consensus strategy is needed to ensure that ledgers are consistent across the different nodes.[153] This means that the data stored on blockchains is largely resistant to modification, as it is difficult to change any block retroactively without altering all subsequent blocks, which requires consensus.[154] Consequently, blockchains are often described as "immutable".[155]

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145 At 3.
146 Jimi S. "Blockchain: What are nodes and masternodes?" (06 September 2018) Medium <www.medium.com>.
147 S. "Blockchain: What are nodes and masternodes?".
148 Bashir, above n 125, at 17.
149 Zheng and others, above n 131, at 358.
150 At 358.
151 At 358. For more information on the Byzantine Generals Problem see L. Lamport, R. Shostak and M. Pease "The Byzantine Generals Problem" (1982) 4 Transactions on Programming Languages and Systems 382.
152 At 358.
153 Zheng and others, above n 131, at 358.
154 Schulz and Feist, above n 140, at 3.
155 Shubhani Aggarwal and Neeraj Kumar "Basics of Blockchain" (2021) 121 Advances in Computers 132, at 140. Note that there are rare cases where a blockchain can be tampered, for example a "fifty-one percent attack" can succeed where attackers gain more than half of the computing power on the blockchain. See Shubhani Aggarwal and Neeraj Kumar "Attacks on blockchain" (2021) 121 Advances in Computers 399.

The most common consensus mechanism is Proof of Work (PoW).[156] This mechanism uses nodes to solve a cryptographic problem; these are known as "miners", while the PoW algorithm is called "mining".[157] When the answer to the PoW problem is found, it is broadcast to the entire network of nodes, which all confirm the solution before working on the next block.[158] This calculation is time-consuming and requires a significant amount of computational power, however it is necessary to ensure the network is secure.[159] The "intrinsic difficulty" of mining, and the fact that the blocks are chained together, secures the blockchain, as it is "too costly in terms of computational resources" for an attacker to recreate a chain.[160]

C Blockchain models: public, private and hybrid networks

There are three distinct categories of blockchain networks: public networks, permissioned networks, and hybrid networks.[161] The public-permissionless blockchain is a highly decentralised system where data is publicly available, and every node is permitted to verify and add transactions to the blockchain.[162] Bitcoin and Ethereum are both examples of public-permissionless blockchain models. In a public network, anyone can "join, read and write to a public network", as there are no special permissions required to access the blockchain.[163]

Comparatively, a permissioned blockchain requires users to have special permission to access the network.[164] These networks limit who can manipulate the blockchain to pre-approved participants.[165]

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[156] Shubhani Aggarwal and Neeraj Kumar "Cryptographic consensus mechanisms" (2021) 121 Advances in Computers 211, at 212.
[157] Zheng and others, above n 131, at 359.
[158] At 359.
[159] Sebastien Meunier "What is Blockchain and How Does This Revolutionary Technology Work?" in Alastair Marke (ed) *Transforming Climate Finance and Green Investment with Blockchains* (1st ed, eBook ed, Academic Press, 2018) 23 at 27.
[160] At 27.
[161] Welfare, above n 128, at 37.
[162] At 37-38.
[163] At 38.
[164] At 39.
[165] Schulz and Feist, above n 140, at 3.

Lastly, there are two types of "hybrid" blockchain networks; public-permissioned network and private-permissionless networks.[166] A public-permissioned network contains components of both public and permissioned blockchains, as the data and transaction history are publicly available, but nodes in the network must have pre-approved permissions to verify and add transactions.[167] Comparatively, in a private-permissionless network, anyone can verify or add transactions, however, only pre-approved nodes can view the data or transaction history.[168]

D Smart contracts

Another technological development is the creation of blockchain enabled smart contracts.[169] A smart contract is a "computerised transaction protocol" under which the terms and conditions of the contract are "embedded in computer code" and are automatically executed once the terms and conditions are fulfilled.[170] The utility of smart contracts can be illustrated by the following analogy to vending machines:[171]

> Unlike a person, a vending machine behaves algorithmically; the same instruction set will be followed every time in every case. When you deposit money and make a selection, the item is released. There is no possibility of the machine not feeling like complying with the contract today, or only partially complying.

Because smart contracts are stored on the blockchain, they are distributed and immutable. Furthermore, smart contracts remove the need for trust because contractual obligations are automatically executed by code.[172] This can be contrasted with traditional contractual arrangements where parties need to trust each other to fulfil their obligations.

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[166] At 3.
[167] At 4.
[168] At 4.
[169] It is worth noting that smart contracts and blockchain are distinct technologies and smart contracts do not necessarily require blockchain technology to be executed. See International Swaps and Derivatives Association *Smart Contracts and Distributed Ledger – A Legal Perspective* (White Paper, August 2017) at 8.
[170] At 370; Dong Xiaoqun and others "Blockchain and emerging digital technologies for enhancing post-2020 climate markets" (World Bank, Working Paper, 2018) at 17.
[171] Swan, above n 130, ch 2.
[172] Shubhani Aggarwal and Neeraj Kumar "Blockchain 2.0: Smart contracts" (2021) 121 Advances in Computers 301, at 307.

E Summary: the central characteristics of blockchain technology

The compatibility of blockchain technology and the Paris Agreement can be illustrated by reference to the fundamental characteristics they share.[173] Firstly, the distributed nature of blockchain technology aligns with the decentralised ethos of the Paris Agreement, which relies on trusted and transparent exchange of information.[174]

Blockchain can also enhance efficiency by removing the need for intermediaries, and smart contracts can be used to automate transactions.[175] Additionally, the data stored on the blockchain is digital, which removes the need for manual documentation.[176] This could be used to overcome bureaucratic inefficiencies in the international climate change regime.

However, the central feature of blockchain is that it enables a high level of trust among parties; once a data is stored on the blockchain, it is immutable, and is therefore nearly impossible to alter or destroy the information. Furthermore, anyone who has access to the blockchain can view the history of all transactions, and every participant has the exact same copy of the data.[177] This "ground-breaking" level of transparency, combined with the fact that it is nearly impossible to tamper with data once it is stored on the blockchain, fosters trust between participants on the network.[178]

These core characteristics of blockchain technology, particularly transparency and immutability, could be used to overcome the lack of trust among states in international climate change, and ultimately promote greater climate ambition. This is particularly necessary given that the world is currently not on track to meet the two degrees Celsius temperature goal.[179]

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[173] Climate Ledger Initiative *Navigating Blockchain and Climate Action: An Overview*, above n 16, at 19.
[174] At 19.
[175] At 19 and 41.
[176] Aggarwal and Neeraj Kumar "Basics of Blockchain", above n 151, at 140.
[177] Schulz and Feist, above n 140, at 3; Welfare, above n 128, at 11.
[178] Leonardo Paz Neves and Gabriel Aleixo Prata *Blockchain Contributions for Climate Finance: Introducing a Debate* (Konrad-Adenauer-Stiftung Regional Programme Energy Security and Climate Change in Latin America, September 2018) at 19.
[179] Climate Action "UNFCCC: Climate commitments 'not on track' to meet Paris Agreement Goals" (02 March 2021) <www.climateaction.org>.

V Opportunities for Blockchain

Blockchain could contribute to greater stakeholder involvement, transparency and engagement and help bring trust and further innovative solutions in the fight against Climate Change.

- Alexandre Gellert Paris, Associate Programme Officer at the UNFCCC.[180]

The Paris Agreement represents a paradigm shift in international climate change law. This shift has provided a "new hope" for the United Nations climate change regime.[181] However, the difficulty now lies in the actual implementation of the Agreement. Arguably, blockchain has a "critical role to play in the profound transformation" required to ensure the Paris Agreement is a success.[182] The focus of this paper is on two of the areas where blockchain has the greatest potential to facilitate climate action: climate finance flows and climate change mitigation.

A Blockchain for climate change mitigation

In terms of climate change mitigation, blockchain technology could be used to facilitate improved emission tracking to monitor progress towards NDCs, and enhance voluntary cooperation under the art 6.2 carbon market mechanism. These are discussed in turn below.

1 Improved emissions tracking

Under art 13.7 of the Paris Agreement, Parties are required to regularly provide a national inventory of GHG emissions and removals, as well as the information necessary to track progress towards NDCs. Reliable GHG inventories are necessary to track parties' individual progress towards achieving their NDCs, as well as the collective progress towards the long-term temperature goal.[183]

However, tracking GHG emissions has high costs and can be overly time consuming.[184] Developing countries in particular may struggle to fulfil their transparency requirements, leading

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[180] UNFCCC "The Good, The Bad And The Blockchain" (17 May 2021) <www.UNFCCC.com>.
[181] Bodansky, above n 14, at 318.
[182] Climate Ledger Initiative *Navigating Blockchain and Climate Action: An Overview*, above n 16, at 9.
[183] Justin Goodwin and Aether Kelly Kizzier *Elaborating the Paris Agreement: National Greenhouse Gas Inventories* (Center for Climate and Energy Solutions, 2018) at 1.
[184] Climate Ledger Initiative *Navigating Blockchain and Climate Action: An Overview*, above n 16, at 41.

to information that is "outdated and non-comprehensive".[185] Furthermore, the Paris Agreement's bottom-up architecture has led to "complexity and variance" among NDCs.[186] For example, there are significant differences in how countries express their individual targets; some countries pledge GHG reductions as a percentage relative to a "business as usual" scenario, while others pledge absolute emission reduction targets relative to a historic base year, which can vary from 1990 to 2014.[187] Furthermore, there are differences in what GHG emissions countries include in their NDCs; for example, China only includes carbon dioxide in its NDC.[188] Parties also have the discretion to decide which sectors are covered by their NDCs, with land use being often excluded.[189] This vast diversity of NDCs makes comparison difficult, and therefore undermines the ability of state and non-state actors to monitor progress towards achieving the voluntary pledges.

Blockchain technology can provide greater transparency as to how data is collected and reported, as well as reducing the time and costs associated with data collection.[190] This would ultimately enhance tracking of GHG emissions, which is necessary to monitor progress towards NDCs. Furthermore, smart contracts could help automate these processes, thereby lowering transaction costs.[191] For example, smart contracts could be used to improve verification processes, by encoding the processes for data verification to ensure its integrity and accuracy.[192] Artificial Intelligence could also be used to compare results from other similar activities to detect any irregularities.[193] However, more research is needed in this area.

Overall, publicly recording GHG emissions on the blockchain would ensure they are accessible and easily comparable. This would enable greater monitoring of progress made towards NDCs and the long-term temperature goal, in line with the Paris Agreement's transparency

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185 Weikmans, van Asselt and Roberts "Transparency requirements under the Paris Agreement and their (un)likely impact on strengthening the ambition of nationally determined contributions (NDCs)", above n 115, at 522.
186 Lewis C King and Jeroen van den Bergh "Normalisation of Paris agreement NDCs to enhance transparency and ambition" (2019) 14 Environmental Research Letters 1 at 1.
187 At 2.
188 At 2.
189 At 2.
190 Climate Ledger Initiative *Navigating Blockchain and Climate Action: An Overview*, above n 16, at 32.
191 At 11.
192 Climate Ledger Initiative *Blockchain for Climate Action and the Governance Challenge* (Report from INATBA and CLI, 2020) at 14.
193 At 14.

requirements. Furthermore, the immutability of the blockchain database would make it nearly impossible for data to be tampered with, which would increase trust in the recorded information.

2 Carbon markets

Another promising application of blockchain technology is improved carbon emissions trading. Article 6.2 establishes a decentralised, bottom-up approach to carbon markets that requires Parties to unilaterally "ensure environmental integrity and transparency" and "apply robust accounting to ensure, inter alia, the avoidance of double counting". However, heterogeneous emission accounting systems make it difficult to assess, track and compare state actions.

Currently, lack of transparency and robust accounting undermines the environmental integrity of carbon market mechanisms, which in turn compromises trust between Parties.[194] Blockchain technology could provide a solution to these challenges in two regards; first, blockchain could improve the MRV of mitigation actions.[195] Second, blockchain could act as a "meta-registry" by linking the heterogeneous emission trading systems on one, transparent, ledger.[196]

a Monitoring, reporting and verification of mitigation actions

The decentralised nature of the Paris Agreement necessitates "new approaches to registries and tracking systems".[197] Blockchain could be used to automate bookkeeping of ITMO transfers between Parties, "ensuring that there is only one Party holding the ITMO at any time".[198] This would eliminate the risk of double counting, which occurs when a GHG emission reduction is counted more than once towards achieving mitigation targets.[199] Where an ITMO transaction is

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194 Schletz, Franke and Salomo "Blockchain Application for the Paris AgreementCarbon Market Mechanism—A Decision Framework and Architecture", above n 80, at 1.

195 At 2.

196 At 2. Note that there is some debate about the efficacy of emissions trading schemes for mitigation purposes. See for example Rebecca Pearse and Steffen Böhm "Ten Reasons Why Carbon Markets Will Not Bring about Radical Emissions Reduction" (2015) 5 Carbon Management 325; Kathleen McAfee "Green Economy and Carbon Markets for Conservation and Development: a Critical View" (2016) 16 International Environmental Agreements: Politics, Law and Economics 333; Steffen Böhm and others "Greening Capitalism? A Marxist Critique of Carbon Markets" (2012) 33 Organisation Studies 1617. However, this debate is outside the scope of this paper. Instead, the focus is on how blockchain technology could be used to improve emissions trading schemes, and it is assumed that such schemes are a cost effective and efficient method of emission reductions.

197 Climate Ledger Initiative *Navigating Blockchain and Climate Action: An Overview*, above n 16, at 13.

198 Schletz, Franke and Salomo "Blockchain Application for the Paris Agreement Carbon Market Mechanism—A Decision Framework and Architecture", above n 80, at 10.

199 At 3.

conducted, the nodes (Parties) would determine whether the transaction is authentic, before conducting the appropriate corresponding adjustments.[200] If the transaction is entered in accordance with the protocol rules it will be validated, and all nodes will have the same copy of the data. Furthermore, participants would be able to trace ITMOs from beginning to end, which will increase trust in the carbon market.[201] This would encourage states to accurately collect and record data, as they would be quickly exposed if they failed to do so. The decentralised and immutable nature of blockchain would also ensure resilience against attacks, and Parties could have confidence that the data has not been tampered with.

Blockchain enabled smart contracts also have the potential to reduce administrative costs. Currently, ensuring environmental integrity of mitigation outcomes requires a significant amount of manual verification by independent auditors, which is inefficient and costly.[202] Smart contracts could automate existing verification processes, thus reducing the "unnecessary paperwork and communication because all actors have access to the latest version of the contract" which would be digitally signed and automatically stored on the blockchain.[203]

Blockchain also has significant potential to "open up existing and create new carbon markets for a wider range of players, including smaller businesses and individuals".[204] Traditionally, participation in emissions trading has predominantly been limited to large, multinational corporations, while small emitters have been excluded, due to the transaction costs associated with MRV of market mechanisms.[205] By making MRV more cost effective, and removing intermediaries, the scope of emissions trading schemes could be expanded to include smaller emitters, such as businesses and individuals, ultimately facilitating more direct, and simple, trading within carbon markets.[206] While this has the potential to be one of the most effective

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[200] At 10.
[201] At 7.
[202] Climate Ledger Initiative *Blockchain Potentials and Limitations for Selected Climate Policy Instruments*, above n 139, at 42.
[203] Laura Franke and Marco Schletz and Søren Salomo "Designing a Blockchain Model for the Paris Agreement's Carbon Market Mechanism" (2020) 12 Sustainability 1 at 5.
[204] Jemma Green "Solving The Carbon Problem One Blockchain At A Time" (19 September 2018) Forbes <www.forbes.com>.
[205] Climate Ledger Initiative *Blockchain Potentials and Limitations for Selected Climate Policy Instruments*, above n 139, at 32.
[206] At 32.

blockchain applications, more work is needed before the full potential of this nascent technology can be realised.

b Linking carbon markets with blockchain

Blockchain provides a bottom-up solution to linking carbon markets without forcing "homogeneous standardisation" across those diverse markets.[207] Carbon markets are "linked" when "a participant in one system can use a carbon unit issued under another system to meet compliance obligations".[208] There are various arguments in favour of linking ETS; trading between heterogeneous emissions trading schemes can facilitate "larger, deeper, and more liquid markets, less susceptible to manipulation and that more effectively price carbon emissions".[209] Furthermore, it can reduce the likelihood of carbon leakage and reduce administrative costs.[210] Politically, a multi-jurisdictional scheme might create "momentum for climate action" and therefore increase pressure on free-riding states.[211]

However, various hurdles have inhibited effective linking of carbon markets; failure to coordinate MRV provisions, double counting and loss of regulatory autonomy have all been identified as obstacles to linking carbon markets.[212] Furthermore, carbon trading schemes can be undertaken at a regional, national, or even subnational level.[213] Given the array of carbon markets across these different levels, it is unsurprising that carbon trading schemes vary significantly in terms of scope, design, and implementation.[214] This makes direct trading between different schemes difficult.

Blockchain provides an opportunity to link carbon markets in a way that is consistent with the bottom-up ethos of the Paris Agreement. One, suboptimal, option is to create a single distributed

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[207] Xing Chen and Ashley D. Lloyd *Understanding the Challenges of Blockchain Technology Adoption: Evidence from China's Developing Carbon Markets* (Proceedings of the 54th Hawaii International Conference on System Sciences, 2021) at 5648.
[208] Justin D. Macinante *Effective Global Carbon Markets* (Edward Elgar Publishing, Cheltenham, 2019) at 76.
[209] At 5.
[210] At 5.
[211] For more information on carbon market linking, see Marissa Santikarn and others *A Guide to Linking Emissions Trading Systems* (International Carbon Action Partnership, 2018).
[212] Chen and Lloyd, above n 203, at 5648.
[213] Adrian Jackson "Networked Carbon Markets" in Alastair Marke (ed) *Transforming Climate Finance and Green Investment with Blockchains* (1st ed, eBook ed, Academic Press, 2018) 255 at 256.
[214] At 255.

ledger that contains all the emission units to be assigned and traded.[215] The benefit of this is that all carbon trades will be contained on a single ledger, which would enable all emission units to be easily tracked and audited.

However, Justin Macinante notes that countries will be hesitant to surrender autonomy to a single, homogenised, carbon market.[216] Therefore, a more feasible option is to facilitate trading between separate carbon markets, which would be able to maintain control over their own ledgers, and internal carbon market processes could continue to be run in accordance with local laws and regulations, while still enabling trade across the different markets.[217] This approach would also be more flexible, as jurisdictions would be to join or leave the market relatively easily.[218] This has the potential to support global linking of carbon markets in accordance with the bottom-up ethos of the Paris Agreement.

Such an approach is currently being explored by the World Bank's "Climate Warehouse". This project established a "blockchain-based accounting platform" that links heterogeneous accounting systems on a publicly available database.[219] This meta-registry would be able to connect to country, regional, and institutional carbon market registries.[220] If a participant makes changes to the information in their system, that change is added to the blockchain and distributed among participants, which are time stamped and cannot be altered retroactively.[221] This in-turn encourages trust among participants, who can easily track mitigation outcomes across jurisdictions. This provides a promising, real world example of how blockchain could improve carbon market mechanisms, and potentially lead to an increase in climate action.

B Climate finance

Blockchain could also prove particularly beneficial in the area of climate finance. Alastair Marke and Bianca Sylvester note that "the lack of trust and transparency in the global climate finance

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[215] At 256.
[216] Macinante, above n 204, at 226.
[217] At 5.
[218] At 149.
[219] Schletz, Franke and Salomo, "Blockchain Application for the Paris Agreement Carbon Market Mechanism—A Decision Framework and Architecture", above n 80, at 5.
[220] At 5.
[221] The World Bank "The World Bank Group Climate Warehouse (02 December 2019) www.worldbank.org>.

landscape provides an excellent ground on which to deploy blockchain technology".[222] Lack of trust and transparency results in increased transaction costs, which inhibits effective mobilisation of climate finance and prevents private sector engagement.[223] Blockchain technology could be utilised to effectively overcome these difficulties and provide real benefits in this area of international climate change law.

There are three main challenges facing the climate finance regime: the "funding gap", which describes the vast difference in the funds needed to keep the temperature within the two degrees Celsius limit, and what has been pledged.[224] The second challenge is the "transparency gap", which is one of the biggest issues facing the climate finance regime.[225] For example, in 2016, just over half of donor countries observed the climate finance transparency requirements under the UNFCCC.[226] This lack of transparency results in "unnecessary barriers in raising funds plus delays in approving and implementing climate change projects urgently needed in the most vulnerable countries".[227] Finally, the "efficiency gap" describes the difficulty many developing countries face meeting the "stringent" accreditation requirements of international climate funds.[228]

The benefits of blockchain for climate finance will be discussed by reference specifically to the Green Climate Fund (GCF). The GCF is a United Nations initiative that aims to distribute climate finance to developing countries. As the largest international climate fund, the GCF plays a central role in the international climate finance landscape, hence why it was chosen to illustrate the benefits of blockchain.[229] Therefore, the rest of this section will examine how blockchain could benefit the GCF, noting that many of the benefits discussed would be applicable beyond the context of the GCF.

1 Blockchain for the Green Climate Fund

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[222] Marke and Sylvester, above n 93, at 37.
[223] Climate Ledger Initiative *Navigating Blockchain and Climate Action: An Overview*, above n 16, at 40.
[224] Marke, above n 1, at xxxvi.
[225] At xxxvi.
[226] At xxxvi.
[227] At xxxvi.
[228] At xxxvi.
[229] Green Climate Fund "About GCF" <www.greenclimate.fund>

One of the main issues related to the GCF is the accreditation process. Access to GCF funding is granted based on "complex bureaucratic procedures".[230] Rather than implementing projects directly, the GCF works with partners (which can be nonprofit, national, international, public, or private), who are given responsibility for carrying out activities.[231] To become a partner, the GCF must confirm whether a prospective partner has the capacity to comply with the Fund's policies and execute the necessary activities.[232] This process of accreditation is "resource intensive", and as a result it is difficult for institutions to become accredited.[233] Furthermore, there is a significant backlog of applications due to the Secretariat's lack of capacity.[234]

Blockchain could overcome this "efficiency gap" by reducing the administrative costs of accreditation procedures through transparent, peer-to-peer, climate finance transactions that have clear standards and safeguards.[235] Currently, the GCF encourages trust through the accreditation process, which as noted is costly and time-consuming. Blockchain can alleviate this by allowing parties to coordinate their activities "without needing to know or trust one another, and without requiring a central coordinating authority".[236] By creating a public register of transactions, financial flows are fully transparent along parties. This would reduce the need for traditional oversight measures and thus reduce administrative costs of accreditation.

This increased transparency would also reduce the risk of fraud and corruption, ensuring that funds are used for their intended purpose. The United Nations Development Programme has found that:[237]

> Maximising the effectiveness of climate finance must include steps to reduce the potential for corruption, as large influxes of resources coupled with an imperative to spend can create conditions ripe for corruption.

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230 Schulz and Feist, above n 259, at 3.
231 Green Climate Fund "Partners" <www.greencline.fund>.
232 Schulz and Feist, above n 259, at 6.
233 Niranjali Amerasinghe, Joe Thwaites and Caitlin Smith *Key Policy Issues in the Green Climate Fund* (World Resources Institute, Washington, DC, 2019) at 51.
234 At 51.
235 Schulz and Feist, above n 259, at 5.
236 At 5.
237 United Nations Development Programme *Staying on Track: Tackling Corruption Risks in Climate Change* (2017) at 5.

The risk of corruption can be reduced by "adopting strategies to promote transparency… and ensure adequate monitoring, reporting and verification".[238] However, "complexity and fragmentation of the global climate finance architecture" makes it difficult to monitor climate finance to prevent corruption.[239]

Aside from the GCF, there is an array of funds channeling climate finance flows, these can be multilateral, bilateral and or regional, while an increasing number of recipient countries have set up national climate change funds.[240] The diversity of available funding mechanisms makes it difficult to track climate finance flows, and therefore increases the risk of corruption. Because data stored on a blockchain is immutable, it will be nearly impossible to create inconsistent data entry or make a fraudulent change once the nodes have confirmed the transaction. Furthermore, every peer on the network has the same copy of the data, which is coded and time stamped, therefore finance will be easily traceable, thus further minimising the risk of corruption.

Finally, smart contracts could also be used to prevent governments "misreporting and backpedalling" on financial commitments.[241] For example, in 2016 the US agreed to pay three billion US dollars into the GCF. One billion was paid under the Obama administration, however when the US later pulled out of the Paris Agreement, this created a two-billion-dollar gap in the GCF.[242] Using smart contracts would minimise opportunities for similar repudiation of financial commitments, as the execution of contracts would be guaranteed.[243] To be effective, Parties must underpin their promises with a monetary stake, which is lost if the promise is unfulfilled.[244] The benefit of this is that it helps create trust in the international arena and could encourage more ambitious commitments from those that are worried about being "cheated upon" by more

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[238] At 5.
[239] Leah Good "Overview of the Global Climate Finance Architecture" Transparency International <knowledgehub.transparency.org>.
[240] Climate Funds Update "Global Climate Finance Architecture" (2020) <www.climatefundsupdate.org>.
[241] Climate Ledger Initiative *Blockchain Potentials and Limitations for Selected Climate Policy Instruments,* above n 139, at 45.
[242] Megan Bowman and Stephen Minas "Resilience through interlinkage: the green climate fund and climate finance governance" (2012) 19 Climate Policy 342 at 443; Bernhard Reinsberg "Three ways blockchain could get the world to act against the climate crisis" (12 June 2020) The Conversation <www.thecoversation.com>.
[243] Bernhard Reinsberg "Fully-automated liberalism? Blockchain technology and international cooperation in an anarchic world" (2021) 13 International Theory 287 at 300.
[244] At 301.

powerful states.[245] Additionally, smart contracts guarantee the execution of a contract, thus eliminating intermediaries and reducing costs.[246]

In sum, blockchain has the potential to close the so-called "transparency" and "efficiency" gaps. This in turn will help upscale the amount of climate finance available, in-turn closing the "funding" gap.

2 Summary: Blockchain potential for climate finance

While the preceding discussion demonstrated the potential benefits of blockchain in relation to the GCF specifically, it is worth noting that blockchain could be used to improve the climate finance ecosystem more generally. One of the main benefits provided by blockchain is its potential to accelerate transfer of climate finance to beneficiaries by removing the need for intermediaries and thus reducing transaction costs.[247] For example, the "COCOA Initiative" enables donors to transparently transfer financial resources to beneficiaries using smart contracts.[248]

Blockchain could also be used to facilitate private sector investment. It is widely recognised that substantially more financial resources are required to support mitigation of, and adaptation to, climate change in developing countries.[249] Therefore, the private sector will be a crucial source of climate funding. Private sector investment makes up the majority, 62 percent, of global climate finance flows.[250] These private sector contributions need to maininted, or preferably increased. However, an "enduring challenge" of the climate finance regime is encouraging international private investment in developing countries where the risks are higher.[251] Improved transparency gives private investors more confidence that the money they are contributing is going to the intended project, while smart contracts could be used to provide up-to-date progress reports.[252]

[245] Bernhard Reinsberg "Three ways blockchain could get the world to act against the climate crisis" (12 June 2020) The Conversation <www.thecoversation.com>.
[246] Neves and Prata, above n 174, at 29.
[247] Climate Ledger Initiative *Navigating Blockchain and Climate Action: An Overview*, above n 16, at 41.
[248] At 40.
[249] Alexander Harris "A Conversation with Masterminds in Blockchain and Climate Change" in Alastair Marke (ed) *Transforming Climate Finance and Green Investment with Blockchains* (1st ed, eBook ed, Academic Press, 2018) at 17.
[250] At 17.
[251] At 17.
[252] At 17.

Blockchain could further enable direct, and secure, private sector investment in small-scale projects, as well as improving the visibility of investment opportunities.[253]

Furthermore, the consensus mechanisms could "guarantee that information regarding the transfer of those resources is validated within a few minutes".[254] Transparency would be ensured because all verified participants would be able to validate the information recorded on the blockchain.[255] This would enable "all the information regarding financial resources (and other forms of climate support, such as technology transfer and capacity-building)" that are received and provided, to be easily accessible and verifiable.[256] This would minimise opportunities for fraud and improve the legitimacy of what climate actions are funded.

In addition, blockchain does not require third party involvement, therefore, it could be used to provide financial services in developing countries that lack access to financial infrastructure, so-called "banking the unbanked".[257] There have also been discussions as to how blockchain could facilitate crowdfunding and peer-to-peer financial transactions to raise funds for climate related projects.[258]

C Blockchain for climate action: overview

Climate change mitigation and the provision of climate finance are two of the core objectives of the Paris Agreement. To be effective, both objectives require comprehensive and transparent exchange of information. However, the bottom-up nature of the Paris Agreement has made achieving the necessary transparency complex.

Blockchain is an innovative option that provides obvious benefits in terms of reduced administrative costs, enhanced transparency, and increased security, all of which will increase trust between Parties and ultimately promote greater ambition. This paper has identified two key

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[253] Schulz and Feist, above n 140, at 3.
[254] Climate Ledger Initiative *Navigating Blockchain and Climate Action: An Overview*, above n 16, at 41.
[255] At 41.
[256] At 41.
[257] For more information Jane Thomason and others "Blockchain—Powering and Empowering the Poor in Developing Countries" in Alastair Marke (ed) *Transforming Climate Finance and Green Investment with Blockchains* (1st ed, eBook ed, Academic Press, 2018) at ch 10.
[258] For more information Climate Ledger Initiative *Navigating Blockchain and Climate Action: An Overview*, above n 16, at 58-64.

areas where blockchain technology could be used to accelerate climate action: climate change mitigation and climate finance. In the context of mitigation, blockchain could be used to improve tracking of GHG emissions, and enable greater monitoring of progress made towards NDCs. Furthermore, the decentralized nature of the art 6.2 carbon market mechanism could benefit from a blockchain application.

There are also various benefits of blockchain technology in the context of climate finance; blockchain could provide transparency and security to climate finance initiatives such as the GCF. Blockchain can also enhance trust between donors and recipients, as the financial flows can be easily tracked, almost in real time, on the blockchain.

However, despite these promising opportunities for blockchain to enhance climate action, there are significant costs and trade-offs associated with this technology, which are discussed in the following chapter.

VI A Double-Edged Sword: Blockchain Challenges and Risks

As demonstrated in the preceding chapter, technological change, such as blockchain applications, has the potential to provide "unprecedented opportunities" to improve human welfare and accelerate climate action.[259] However, there is the "imminent risk that unregulated digitalization may create entirely new challenges, or further exacerbate existing ones".[260]

The following chapter will analyse the technical and political challenges associated with the use of blockchain that would need to be overcome before blockchain could realistically be used to implement the Paris Agreement.

A Technical challenges

Blockchain is a new technology, therefore it is unsurprising that there are various technical challenges associated with its implementation. Alexis Rocamora and Aryanie Amellina note that as blockchain "moves progressively into a more mature phase, blockchain will likely address

[259] Schulz and Feist, above n 140, at 1.
[260] At 2.

most of its issues".[261] However, despite rapid, and continuing, improvements in blockchain technology since the inception of Bitcoin, technical limitations continue to undermine the efficacy of blockchain technology.

1 Transaction speed

The first challenge is transaction speed, which is slow in comparison to other digital databases.[262] For example, Bitcoin validates only seven transactions per second, while the Ethereum blockchain validates twenty-five transactions per second.[263] Comparatively, the transaction rate of the Visa network is approximately 2000 per second.[264] Deloitte notes that "blockchain's sluggish transaction speed is a major concern for enterprises that depend on high-performance legacy transaction processing systems".[265] However, in the context of carbon markets, Franke and others predict that the annual volume of transactions would be supported by the majority of blockchains.[266] Furthermore, the issue of transaction speed will likely be ameliorated as the technology is developed, and therefore should not pose an insurmountable barrier to the adoption of blockchain to the international climate change regime.

2 Energy consumption

Another risk of using blockchain is its high energy consumption. The proof-of-work consensus mechanism requires nodes to solve an encrypted puzzle. While this helps secure the network, it also "creates significant demand for electricity" and has resulted in Bitcoin being dubbed a "dirty currency".[267] According to the University of Cambridge Bitcoin Electricity Consumption Index, Bitcoin uses the same amount of electricity in one year as the entire country of New Zealand.[268] This has led researchers to suggest that "Bitcoin emissions alone could push global warming

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[261] Alexis R. Rocamora and Aryanie Amellina *Blockchain Applications and the Sustainable Development Goals* (Institute for Global Environmental Strategies, Report, August 2018) at 69.
[262] At 70.
[263] Meunier, above n 155, at 31.
[264] Rocamora and Amellina, above n 256, at 70.
[265] Aniket Dongre, Amanpreet Arora, David Schatsky "Blockchain and the five vectors of progress" (28 September 2018_ Deloitte Insights <www.deloitte.com>.
[266] Schletz, Franke and Salomo "Blockchain Application for the Paris AgreementCarbon Market Mechanism—A Decision Framework and Architecture", above n 80, at 8.
[267] Delton Chen "Utility of the blockchain for climate mitigation" (2018) 1 JBBA 75 at 76; Katie Martin and Billy Nauman "Bitcoin's growing energy problem: 'It's a dirty currency" (20 May 2021) Financial Times <www.ft.com>.
[268] This statistic is current as of October 2021. See Cambridge Bitcoin Electricity Consumption Index "Comparisons" <www.cbeci.org>.

above two degrees Celsius".[269] Therefore, it may appear paradoxical to suggest that Blockchain could be used to implement the Paris Agreement when it might exacerbate climate change.

However, the energy consumption of blockchain is less of an issue for private-permissioned networks.[270] Furthermore, Rocamora and Amellina note that the high level of energy consumption is "likely to be specific to Bitcoin, which, as the first blockchain, suffers from structural inefficiencies in its mining process" that can be improved where alternative consensus mechanisms are used.[271] This implies that alternative blockchains have the potential to be more energy efficient. Indeed, the "proof-of-stake" (PoS) mechanism has already been developed to be more energy efficient and overcome this central criticism of blockchain.[272]

Despite improved energy efficiency, this paper does not necessarily endorse the use of Proof-of-Stake in the international climate change law due to the inherent risk that those with less resources miss out. It is arguable that PoS is actually fairer than PoW, as it does not require nodes to have significant computing power. In a PoW system, those with more and better equipment have a better chance of getting to create the new block. However, under the PoS consensus mechanism, validators (the equivalent to "miners" in a PoW system) are chosen ostensibly at random.[273] However, to become a validator, nodes must first deposit a "stake", essentially a security deposit, into the network.[274] Nodes have "mining power proportional to the number of tokens they own", therefore, the more "stakes" a validator has, the greater their chance of being chosen to forge the next block.[275] For example, if a miner holds one percent of the network's wealth, they "may only ever mine one percent of the proof-of-stake blocks".[276] Consequently, there is a risk that the "rich-get richer", as miners that have a bigger stake in the network have a higher chance to become a validator, and therefore have greater mining power

[269] Camilo Mora and others "Bitcoin emissions alone could push global warming above 2°C" (2018) 8 Nature Climate Change 931 at 931.
[270] Chen, above n 262, at 76.
[271] Rocamora and Amellina, above n 256, at 70.
[272] Chen, above n 262, at 76.
[273] Shubhani Aggarwal and Neeraj Kumar "Cryptographic consensus mechanisms" (2021) 121 Advances in Computers 211 at 212.
[274] At 213.
[275] John Hargrave and Evan Karnoupakis *Blockchain Success Stories* (1st ed, O'Reilly Media Inc, Sebastopol, 2020), at 23.
[276] Antony Welfare, above n 128, at 49.

than those with less stakes.[277] In order to alleviate this, it would be essential to ensure that all nodes have an equal stake in the network, or there is a risk that poorer countries miss out.

Consensus mechanisms are not limited to PoW and PoS, and there are a variety of protocols available that may alleviate the issues discussed above.[278] One of many options that may be worth considering is "Proof-of-elapsed time (PoET)", which chooses miners at random based on wait time.[279] The benefit of this consensus mechanism is that the chance of being chosen is spread equally across network participants; each node waits for a randomly chosen period, and the first one to complete the waiting time verifies the new block and commits it to the ledger.[280]

To summarise, high energy consumption of certain consensus mechanisms is certainly problematic, particularly from an environmental perspective. However, like the issue of slow transaction speed, this challenge will likely be alleviated as the technology develops. Additionally, alternative consensus mechanisms can be used to reduce the energy intensity required in a PoW system. Therefore, this paper suggests that energy consumption itself should not pose a barrier to the use of blockchain to enhance transparency under the Paris Agreement.

3 Data (in)accuracy

Another issue associated with the use of blockchain is data security. Blockchain technology has the potential to collect significant amounts of data, which is then stored on an immutable ledger. However, while blockchain does provide a decentralised and immutable record of the data, it does not guarantee that that recorded data is correct.[281] Therefore, while the immutability of blockchain may be seen as advantageous, the downside is that it is "extremely difficult to retrospectively alter or remove (false) information once it has been entered into the system".[282] Participants can record false data on the blockchain, and whether it is deliberate or not, the technology will not recognise the inaccuracies.[283] Therefore, it is possible for incorrect data to be

[277] At 49.
[278] For more information on available consensus mechanisms, see Aggarwal and Kumar "Cryptographic consensus mechanisms", above n 268; Antony Welfare, above n 128, at ch 2.
[279] Aggarwal and Kumar "Cryptographic consensus mechanisms", above n 268, at 218
[280] Antony Welfare, above n 128, at 51.
[281] Rocamora and Amellina, above n 256, at 75.
[282] Schulz and Feist, above n 140, at 7.
[283] Rocamora and Amellina, above n 259, at 75.

stored on the blockchain, so long as it is entered in accordance with the protocol rules.[284] This issue - often referred to as "rubbish in, rubbish out" - means that the accuracy of the data is not guaranteed by the technology.[285] For example, a corrupt government could falsify the number of votes they receive, even where votes are counted on the blockchain.[286]

To minimise the risk of inaccurate information being stored on the blockchain, "the accountability of the data provider needs to be ensured" by auditing what data goes is stored on the blockchain.[287] It is expected that such specialised service providers will emerge in the future to address this challenge.[288] Furthermore, Rocamora and Amellina suggest that artificial intelligence could eventually be used to verify the data before it is stored permanently on blockchain.[289] However, further development is needed in this area.

B Political challenges

Many of the technical challenges discussed above will likely be resolved as blockchain technology develops, and therefore should not impede future use of this technology to implement the Paris Agreement. However, issues with blockchain are not limited to technological inefficiencies, and "like any powerful technology, the social and political costs… of nascent blockchain applications remain ambiguous".[290] The following section discusses the political challenges that will ultimately present the greatest impediment to broad adoption of blockchain technology in international climate change law.

1 Data privacy

Firstly, the use of blockchain raises legal and ethical issues, particularly surrounding data privacy. Within the European Union, there is an ongoing debate as to whether a blockchain can

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[284] Climate Ledger Initiative *Blockchain Potentials and Limitations for Selected Climate Policy Instruments,* above n 139, at 23.
[285] At 23.
[286] Rocamora and Amellina, above n 256, at 75.
[287] Climate Ledger Initiative *Blockchain Potentials and Limitations for Selected Climate Policy Instruments,* above n 139, at 23.
[288] Rocamora and Amellina, above n 256, at 75.
[289] At 75.
[290] Peter Howson "Climate Crises and Crypto-Colonialism: Conjuring Value on the Blockchain Frontiers of the Global South" (2020) Frontiers on Blockchain <www.frontiersin.org>.

be compliant with data regulations, namely "the right to be forgotten", enshrined in the 2016 General Data Protection Regulation.[291]

Commentators have also raised concerns of "data colonialism" becoming more pervasive where blockchain is used. For example, in 2017, the World Food Programme developed a "Building Blocks initiative", which uses Blockchain to provide aid to Syrian refugees. However, refugees had to "upload their biometric data onto a shared blockchain to verify their identities".[292] Payment of goods was done using a retinal scan, creating an immutable record of every purchase they make, thus creating significant privacy concerns.[293] Peter Howson argues that such "data colonialism" will "inevitably" result in a significant risk of data breaches, as "sensitive, personally identifiable information for some of the most vulnerable people… being generated and made accessible across agencies" by-way-of blockchain technology.[294]

2 Exacerbate existing inequities

In addition, blockchain itself will not "overcome existing hierarchies in the international system".[295] In fact, Bernhard Reinsberg finds that the use of blockchain may result in "new kinds of power asymmetries".[296] Blockchains, like other technologies, are "always embedded in specific social contexts… and will be deployed in ways that reflect existing power structures".[297] This is particularly pertinent when considering the so-called "digital divide", which may be exacerbated by using blockchain.

Aggarwal and Floridi note that the effectiveness of blockchain depends on:[298]

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[291] Schulz and Feist, above n 140 at 7; and General Data Protection Regulations 2016 (EU), art 17.
[292] Peter Howson, above n 285.
[293] Peter Howson, above n 285.
[294] Peter Howson, above n 285.
[295] Reinsberg "Fully-automated liberalism? Blockchain technology and international cooperation in an anarchic world", above n 238, at 304.
[296] At 304.
[297] At 304.
[298] Nikita Aggarwal and Luciano Floridi *The Opportunities and Challenges of Blockchain in the Fight Against Government Corruption* (Council of Europe Group of States against Corruption, 19th General Activity Report, 2018) 16 at 19.

> … the strength of a country's (digital) infrastructure — the Internet, distributed and cloud computing, electricity supply, and digitized data, all of which power the blockchain, as well as the technological literacy of its population.

Jillian Crandall suggests that "until the digital divide is addressed… blockchain… may actually serve to further entrench digital inequality".[299] The so-called "digital divide" refers to "stark demographic and geographical differences concerning the availability, adoption and use of digital technologies", including "cultural perceptions of digitalisation".[300] This divide between developed and developing countries may be further compounded by the use of blockchain, which will require sufficient digital infrastructure to be operational. To minimise the risk of blockchain exacerbating the digital divide, investments in infrastructure, expertise and pilot projects will be required in developing countries.[301] However, this creates the risk of developing countries becoming blockchain "guinea pigs" while local sovereignty is undermined. This so-called "crypto-colonialism" can be illustrated by reference to Puerto Rico, which became a "test bed" for private investors to trial decentralised funding for hurricane relief through blockchain infrastructure.[302]

Further ethical issues arise where blockchain is used to facilitate emissions trading. Most carbon-offset initiatives are undertaken in developing countries "where land, labour, and other necessary inputs can be sourced cost-effectively for maximum potential profit".[303] For example, Climate Futures has launched a blockchain platform that enables individuals and companies to reduce their net emissions by supporting more climate friendly initiatives, for example installing more "fuel-efficient" cookstoves in Zambia.[304] However, the issue here is that small communities in developed countries, who often have a near neutral carbon footprint, are "framed as more responsible for climate change", thus shifting the blame off developed countries.[305] This

[299] Luke Ottenhof "Crypto-Colonialists Use the Most Vulnerable People in the World as Guinea Pigs" (30 June 2021) Vice <www.vice.com>.
[300] Schulz and Feist, above n 259, at 7.
[301] At 7.
[302] For more information on crypto-colonialism see Ottenhof "Crypto-Colonialists Use the Most Vulnerable People in the World as Guinea Pigs", above n 293.
[303] Peter Howson, above n 285.
[304] Peter Howson, above n 285.
[305] Peter Howson, above n 285.

overlooks the historical contribution of developed countries to the climate crisis and ignores those who are primarily responsible for emissions, for example the fossil fuel industry. [306]

3 Lack of state buy-in

Despite the "undeniable benefits" of blockchain, a fundamental issue is that many problems in the international climate change arena are inherently political, which "cannot simply be done away with through technical solutions".[307] Reinsberg rightly points out that "blockchain technology will challenge neither the primacy of states in global governance nor the preponderance of powerful states within the state community".[308] In other words, blockchain will not change the consent-based nature of international law. Therefore, while certain blockchain applications may appear promising in theory, practical implementation will prove difficult if state consent is lacking.

States, particularly powerful states, will have significant control over the initial design choices, for example, whether to utilise a public network, permissioned network, or a hybrid approach. The degree of system permissioning will always come with trade-offs, which are largely dependent on context,[309] and will be inherently political.[310] Karsten Schulz and Marian Feist note that:[311]

> Distributed Ledger Technology [blockchain] design choices seriously affect the lives of users because of the various effects that digital products have on people's behaviour, attitudes, and needs… system design encourages certain forms of social interaction and human behavior by defining specific rules for users interacting through the network.

In terms of implementing the Paris Agreement, the main advantage of using a permissionless blockchain system is that they are fully decentralised, and anyone can become a node to validate

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[306] Matthew Taylor and Jonathan Watts "Revealed: The 20 Firms Behind a Third of All Carbon Emissions" (09 October 2019) The Guardian <www.theguardian.com>.
[307] Schulz and Feist, above n 140, at 8.
[308] Reinsberg "Fully-automated liberalism? Blockchain technology and international cooperation in an anarchic world", above n 238, at 305.
[309] Schletz, Franke and Salomo "Blockchain Application for the Paris AgreementCarbon Market Mechanism—A Decision Framework and Architecture", above n 80, at 8.
[310] Schulz and Feist, above n 140, at 4.
[311] At 4.

data.[312] This embodies the bottom-up nature of the Paris Agreement, and would enhance transparency, accountability, and credibility.[313]

However, such a system may prove too risky, as it is not controlled by authorised entities.[314] Furthermore, public-permissionless systems tend to be slower and more energy intensive.[315] Comparatively, a private-permissioned model would enable Parties to maintain control over the ledger.[316] Additionally, it would allow Parties to keep information private, and therefore may be more appealing to states who do not want to share detailed information with actors outside of the Paris Agreement.[317] However, because they are private and centrally controlled, private-permissioned systems lack the "truly decentralised" nature of a public-permissionless blockchain, and "might conflict with the bottom-up ethos of the Paris Agreement".[318] Despite these trade-offs, private blockchains are likely the most politically feasible option in terms of encouraging state participation.

A preferable option would be to combine elements of both models by using a hybrid blockchain, such as a public-permissioned blockchain. This would limit those who verify and add transactions to pre-identified stakeholders (namely Parties to the Paris Agreement, however it could also include trusted third parties such international organisations, and expert bodies and non-governmental organisations).[319] However, the data would be publicly available to ensure the transparency requirements under the Paris Agreement are met.

Ultimately, more research is needed to ascertain the feasibility of the available network options, with the final decision being dependent on state preferences. Given that states have historically been hesitant to limit their sovereignty, a public-permissionless blockchain may not be a realistic

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[312] Schletz, Franke and Salomo "Blockchain Application for the Paris AgreementCarbon Market Mechanism—A Decision Framework and Architecture", above n 80, at 9.
[313] At 9.
[314] At 9.
[315] Chen, above n 262, at 76.
[316] Climate Ledger Initiative *Navigating Blockchain and Climate Action: An Overview*, above n 16, at 88.
[317]At 88.
[318] Schletz, Franke and Salomo "Blockchain Application for the Paris AgreementCarbon Market Mechanism—A Decision Framework and Architecture", above n 80, at 9.
[319] Reinsberg "Fully-automated liberalism? Blockchain technology and international cooperation in an anarchic world", above n 238, at 305.

option. Conversely, while a private-permissioned blockchain might be more politically appealing, it does not promote decentralisation and transparency, and therefore undermines the bottom-up nature of the Paris Agreement. Therefore, in the context of implementing the Paris Agreement, a hybrid blockchain system that maintains an adequate level of transparency is preferred. However, it is unclear if states would agree to this level of transparency.

Furthermore, it remains uncertain whether Parties' will be willing to disclose data on their mitigation actions; the Climate Ledger Initiative recently reported that "state's privacy issues and the access to commercially sensitive data as a challenge for the implementation of blockchain in carbon markets".[320] Already, the UNFCCC's attempt to include references to distributed ledger technology (blockchain) in the rulebook for art 6.2 were removed in subsequent iterations.

Ultimately, states are likely to select a private-permissioned blockchain model, which lacks the central benefits of decentralisation and transparency contained on a public blockchain. Overall, there is a risk that large emitters, who have the most to lose if blockchain is successfully implemented, will oppose the use of blockchain if it is not in their best interest to do so. For example, states may resist measures to increase transparency where it will result in further scrutiny of their emissions. Ultimately "the promise of harder commitments that smart contracts can afford thus has the drawback of leaving those states out of its jurisdiction which would need to be constrained the most".[321]

VII Conclusion

Technological innovation is often at the forefront of proposed solutions to anthropogenic climate change. The suggestion that blockchain technology can help put the world on track to meeting Paris Agreement's long term temperature goal, aligns with the global trend towards solutionism; the belief that every problem has a technological solution.[322]

Certainly, blockchain has some promising applications, particularly in the context of the bottom-up and decentralised nature of the Paris Agreement. Blockchain removes the need for

[320] Climate Ledger Initiative *Navigating Blockchain and Climate Action: An Overview*, above n 16, at 188.
[321] At 305.
[322] Ottenhof, above n 295.

intermediaries, while smart contracts can be used to automate transactions. This paper has shown how these characteristics of blockchain could overcome bureaucratic inefficiencies in the international climate change regime.

These core characteristics of blockchain technology, particularly transparency and immutability, could be used to overcome the lack of trust among states in international climate change, and ultimately promote greater climate ambition.

However, while blockchain provides opportunities to accelerate progress towards the Paris Agreement's mitigation and financing goals, it is important to consider whether the benefits of blockchain outweigh the risks. This paper has highlighted the potential technical and political risks associated with the use of blockchain. While many of the technical challenges discussed should be overcome as this nascent technology develops, the arising political challenges pose a real impediment to the broad adoption of blockchain technology in the international climate change regime. Particularly, there is a risk of inequities between developed and developing countries being exacerbated by increased digitisation.

However, the biggest impediment to broad adoption of blockchain technology will likely be unwillingness to accept the increased scrutiny that would come from storing data on a transparent, immutable ledger.

Overall, while blockchain is undoubtedly a revolutionary technology, it is not a silver-bullet solution to the climate crisis.

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