Linking Climate Action Pledges & Carbon Pricing Mechanisms to Alleviate the "Tragedy" of the Global Climate Commons

In Pursuit of an International Governance System to Facilitate the Monitoring, Reporting, and Verification (MRV) Processes for Compiling Greenhouse Gas (GHG) Inventories and the Generation of Mitigation Assets

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Table of Contents

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Introduction

Around the world, economic systems are predicated on the growth paradigm, which asserts that market forces efficiently allocate resources according to the laws of supply and demand. While these neoliberal constructs have enabled enormous strides in economic & human development, they fail to appropriately price the environmental and social injustices associated with our collective economic activity. These environmental and social injustices are known as negative externalities and are central to the economic theory of "Tragedy of the Commons" (TotC); the over-use of a shared resource due to misaligned private incentives for use, management, and protection.[1]

Overview

Climate change is the most prominent case-study of the "Tragedy of the Commons" (TotC) and is widely considered the most pressing issue our species has ever confronted.[2] The tragedy occurs when private incentives related to the use of a shared, community resource are not aligned with maximizing the utility of that shared resources for the overall community. To take an excerpt from Nobel Laureate William Nordhaus' book 'The Climate Casino';

> *"One major lesson from economics is that unregulated markets cannot efficiently deal with harmful externalities...Putting a price on emissions corrects for the underpricing of the externality in the marketplace."*[3]

[1] "Tragedy of the commons - Wikipedia." https://en.wikipedia.org/wiki/Tragedy_of_the_commons. Accessed 21 Dec. 2018.
[2] "Global Warming of 1.5 ºC - IPCC." https://www.ipcc.ch/sr15/. Accessed 21 Dec. 2018.
[3] "Climate Casino | Yale University Press." https://yalebooks.yale.edu/book/9780300212648/climate-casino. Accessed 21 Dec. 2018.

To address this global calamity, governments around the world have arranged a multilateral process for creating agreements and systems, and have pledged to manage the use of The Global Climate Commons ('The Commons') by creating:

1. A governance process and mechanism for the reporting of national GHG emission inventories (and sinks) = GHG Inventory Reporting, or in 'Commons' terms, a process to track the use of The Commons by Parties, and;
2. A governance process and mechanism to allocate rights and obligations related to the use of The Commons, which are ultimately expressed in terms of Parties 'Nationally Determined Contributions' and Parties abilities to work together to support each other in reaching them (Paris Agreement, Article 6).

Background

With respect to these governance processes and mechanisms, a background on the origin of this multilateral system is in order. The Paris Climate Accord ("the Agreement"), adopted in December 2015, is an agreement within the United Nations Framework Convention on Climate Change (UNFCCC) dealing with greenhouse gas emissions (GHG) mitigation, adaptation, and finance that, in the words of WRI contributors, "provides the essential building blocks for universal action to address climate change."[4][5][6]

[4] "Paris Agreement English - unfccc." https://unfccc.int/files/meetings/paris_nov_2015/application/pdf/paris_agreement_english_.pdf. Accessed 21 Dec. 2018.
[5] "The Paris Agreement | UNFCCC." https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement. Accessed 21 Dec. 2018.
[6] "Staying on Track from Paris – Advancing the Key Elements of the Paris ...." http://hubenergetico.com/ciner/staying-on-track-from-paris-advancing-the-key-elements-of-the-paris-agreement/. Accessed 21 Dec. 2018.

The goal of the Agreement is to limit global temperature rise this century to "well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius." Additionally, the agreement aims to strengthen the ability of countries to deal with the negative long-term impacts of climate change by efficiently directing financial flows to those most vulnerable.[2]

To fully achieve the functions of the Agreement, Parties (countries) are working together to design the numerous operational tools for implementing the Agreement. Ultimately, the long-term success of the Paris Agreement rests on these details, and designing these tools well is essential to ensuring environmental integrity, providing support for action, and increasing ambition over time. It is well understood that although these commitments mark the most ambitious collective action to date to fight the adverse effects of GHG emissions & Climate Change, they fall woefully short of achieving the goals laid out by the Agreement. Significantly higher levels of ambition are needed.[78]

One of the Agreements core ingredients for increasing ambition and facilitating implementation is the use of internationally transferred mitigation outcomes (ITMOs) towards Nationally Determined Contributions (NDCs) (Article 6.2), and the market-based mechanism to promote the mitigation of greenhouse gas emissions while fostering sustainable development (Article 6.4).

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[7] "Emissions Gap Report 2018 | UN Environment." 27 Nov. 2018, http://www.unenvironment.org/resources/emissions-gap-report-2018. Accessed 21 Dec. 2018.
[8] "The Economics of the Climate Crisis by José Antonio Ocampo ...." 19 Oct. 2018, https://www.project-syndicate.org/commentary/economics-of-climate-crisis-by-jose-antonio-ocampo-2018-10. Accessed 21 Dec. 2018.

Largely based on its predecessor mechanisms under the Kyoto Protocol, the new Sustainable Development Mechanisms will surely build on, and share features of, the flexible approaches taken by the Clean Development Mechanism (CDM) & Joint Implementation (JI).[9][10]

The primary challenge associated with the voluntary transfer of international mitigation outcomes (ITMOs) rests in the fact that these transfers are generally complex multilateral deals that involve the verifiably-provable generation, exchange, and often-times termination of intangible digital assets that represent specific geo-temporal mitigation outcomes.

Currently, the SBSTAs solution to alleviate this dilemma is for a public registry and centralized settlement platform to execute counterparty clearing. Although this solution would provide the means to ensure double counting is avoided, it is not a robust solution as it relies on a central administrator to account for and process all mitigation outcome transfers, which is subject to abuse in the form of inefficient transfer times and high transactional fees. I posit that the appropriate solution to facilitate the transfer of ITMO's comes in the form of a public registry, that operates on a distributed ledger, and facilitates the fair, efficient, and verifiable transfer of mitigation assets. The immutable nature of distributed ledgers affords us the ability to fully accounted for all mitigation assets, therefore extinguishing the threat of freeloaders and double-counting.

The potential benefits of such a solution are well understood, as demonstrated at the most recent SBSTA meeting which took place in Bangkok, Thailand in September 2018. While discussing matters related to guidance on cooperative approaches referred to in Article 6,

[9] "Kyoto Protocol - unfccc." https://unfccc.int/process/the-kyoto-protocol. Accessed 21 Dec. 2018.
[10] "sustainable development mechanisms sdm - unfccc." https://unfccc.int/files/secretariat/unfccc_budget/application/pdf/factsheet_sdm.pdf. Accessed 21 Dec. 2018.

paragraph 2, the SBSTA made several mentions of potentially utilizing a distributed ledger for tracking the international transfer of mitigation outcomes (ITMOs).[11]

The second core ingredient of the Agreement, found in Article 14, is the ambition mechanism, or "cycles of action". This mechanism "lays out a process to continue strengthening action in a regular and timely way every five years, starting before 2020", and "is what makes the Paris Agreement a dynamic and long-lasting accord that will be responsive to the science of climate change, shifts in technology and economic opportunities, and to growing public support for action."[12]

Termed the 'Global Stocktake', this ambition mechanism is an opportunity for all parties to collectively assess what progress has been made towards achieving the purpose of the Agreement and its long-term global goal (LTGG).[13] The first global stocktake under the agreement was scheduled for 2023, with new NDCs to be submitted by 2025. In realizing that the current set of pledges is inadequate to limit the rise in global temperature to the Agreements target of "well below two degrees Celsius," Parties will initiate this cycle prior to the agreement's anticipated entry into force.[14] In response to this realization, the UNFCCC held a

[11] "Guidance on cooperative approaches referred to in Article 6 ... - unfccc." 9 Sep. 2018, https://unfccc.int/sites/default/files/resource/sbsta48.2_12a_DT_Outcome.pdf. Accessed 21 Dec. 2018.
[12] "Why a Mechanism to Increase Countries' Climate Ambition over Time ...." 7 Dec. 2015, https://www.wri.org/blog/2015/12/why-mechanism-increase-countries-climate-ambition-over-time-makes-good-economic-sense. Accessed 21 Dec. 2018.
[13] "INSIDER: 4 Key Questions for the Design of the Global Stocktake ...." 19 May. 2016, https://www.wri.org/blog/2016/05/insider-4-key-questions-design-global-stocktake. Accessed 21 Dec. 2018.
[14] "World on track for 3C of warming under current global ... - The Guardian." 3 Nov. 2016, https://www.theguardian.com/environment/2016/nov/03/world-on-track-for-3c-of-warming-under-current-global-climate-pledges-warns-un. Accessed 21 Dec. 2018.

special dialogue, termed the Talanoa Dialogue, this year to encourage countries to submit more ambitious pledges before 2020.[15]

After many months of garnering insights from collective inputs, the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement (CMA), and the Subsidiary Body for Scientific and Technological Advice (SBSTA), have recently developed the guidelines for the voluntary transfer of international mitigation outcomes, and other key provisions of the Paris Agreement. These guidelines, largely referred to as the 'Paris Rulebook', and are laid out in the Katowice Texts, which was recently agreed on at COP24 in Katowice, Poland. The Katowice Texts are meant to act as a comprehensive protocol to resolve the technical specifications of the many key provisions of the Paris Agreement, including the instructions to avoid double counting through the accurate and consistent recording and tracking of mitigation outcomes.[16][17][18][19]

The importance of the use of internationally transferred mitigation outcomes (ITMOs) towards NDCs and the Global Stocktake framework cannot be overstated. Market-based mechanisms with a standardized unit of account, coupled with a set of parameters for Parties to facilitate implementation and assess how well they are decarbonizing their economies in relation to their goals is imperative for achieving the overall long-term global goal (LTGG) of limiting

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[15] "2018 Talanoa Dialogue Platform | UNFCCC." https://unfccc.int/topics/2018-talanoa-dialogue-platform. Accessed 21 Dec. 2018.
[16] "Compendium on methods and tools to evaluate impacts of - unfccc." 2 Jan. 2005, https://unfccc.int/files/adaptation/methodologies_for/vulnerability_and_adaptation/application/pdf/consolidated_version_updated_021204.pdf. Accessed 21 Dec. 2018.
[17] "Conference of the Parties serving as the meeting of the ... - unfccc." https://unfccc.int/process/bodies/supreme-bodies/conference-of-the-parties-serving-as-the-meeting-of-the-parties-to-the-paris-agreement-cma. Accessed 21 Dec. 2018.
[18] "Subsidiary Body for Scientific and Technological Advice (SBSTA ...." https://unfccc.int/process/bodies/subsidiary-bodies/sbsta. Accessed 21 Dec. 2018.
[19] "The Katowice Texts Proposal by the President Contents - unfccc." 3 Dec. 2018, https://unfccc.int/sites/default/files/resource/Katowice%20text%2C%2014%20Dec2018_1015AM.pdf. Accessed 21 Dec. 2018.

global temperature rise to well below 2 degrees Celsius above pre-industrial levels this century. These mechanisms and associated transparency framework will ultimately allow Parties to conduct the appropriate Monitoring, Reporting, and Verification (MRV) actions necessary for efficiently decarbonizing their economies, and will assist in directing financial flows to those most vulnerable from the adverse impacts of climate change.

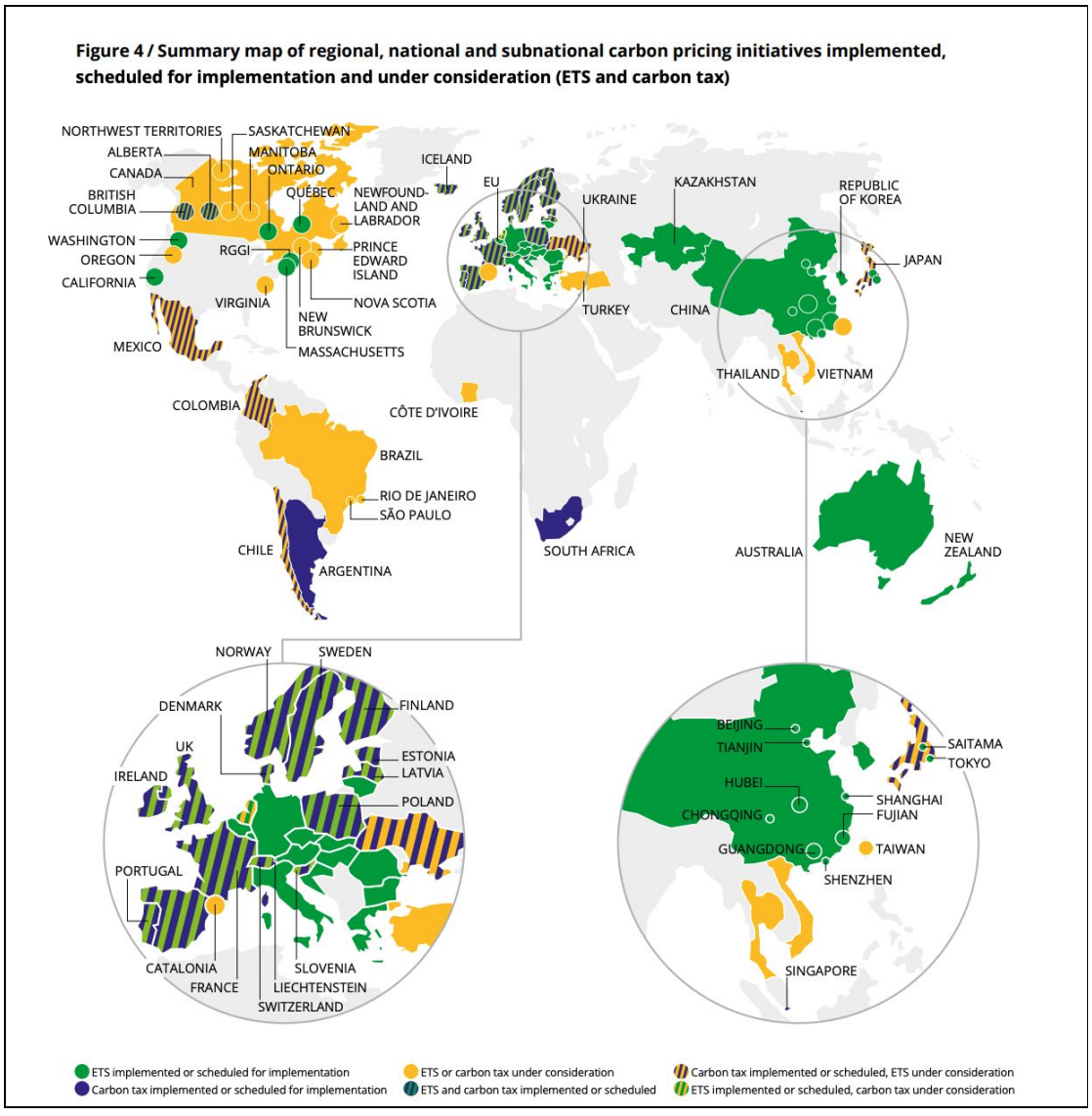
The adoption and ratification of the Paris Accord marked the first-ever global agreement of comprehensive and unified action to limit the adverse effects of GHG emissions and Climate Change structured in a "bottom-up" fashion. Prior to this Agreement, governments have never possessed the will or ability to align interests and commitments to achieve a collective goal in a similar structure. Due to the inability to accurately & efficiently quantify, on a global scale, what had been done, what is being done, and what still needs to be done to address the adverse effects of GHG emissions and anthropogenic climate change, a number of fragmented pricing mechanisms & initiatives have been launched around the world at regional, national, and subnational levels.

According to the World Bank, as of December 2018, 52 carbon pricing initiatives have been implemented or are scheduled for implementation. This consists of 24 Emissions Trading Schemes (ETS), mostly located in subnational jurisdictions, and 23 carbon taxes primarily implemented on a national level.[20] Overall, 46 National jurisdictions, representing about half of global GDP and more than a quarter of global GHG emissions, are a part of a carbon pricing

[20] "Carbon Pricing Dashboard | Up-to-date overview ... - World Bank Group." https://carbonpricingdashboard.worldbank.org/. Accessed 21 Dec. 2018.

initiative. When taken all together, these initiatives cover 11 GtCO2e or 19.5% of global GHG emissions. ETSs account for roughly two-thirds of the covered GHG emissions.[21]

It's also important to note that many Parties of the Agreement see carbon pricing initiatives playing a prominent role in their future, with 88 Parties that have submitted their NDCs planning or considering the use of carbon pricing as a tool to meet their commitments.[20]



Snapshot from World Bank "State and Trends of Carbon Pricing 2018" report

[21] "State and Trends of Carbon Pricing 2018 - Open Knowledge ...." 22 May. 2018, https://openknowledge.worldbank.org/handle/10986/29687. Accessed 21 Dec. 2018.

However, due to the varying degrees of scope and coverage, the fragmentation and heterogeneity of carbon pricing initiatives have created misaligned prices among regional, national, and subnational levels. To once again reference the data compiled by the World Bank, prices of implemented carbon pricing initiatives vary drastically, ranging from less than US$1 up to US$140/tCO2e. Furthermore, approximately three quarters of emissions covered by carbon pricing are priced at less than US$10/tCO2e, which is substantially lower than the price levels that the Carbon Pricing Leadership Coalition deemed are consistent with achieving the temperature goal of the Paris Agreement, in the range of US$40–80/tCO2e in 2020, and US$50–100/tCO2 by 2030.[22]

Currently, only about 1% of emissions covered by carbon pricing initiatives are priced within that range, and the vast majority of emissions are not covered by carbon pricing initiatives. Needless to say, global coverage of carbon emissions is still far from the target identified by the High-Level Panel on Carbon Pricing of 50 percent within the next decade.[23]

To align the various carbon pricing initiatives that currently exist, a comprehensive & transparent method of deriving a unified mitigation value is needed to ensure that the mitigation actions of various pricing initiatives can be traded between schemes, whether at the regional, national, or subnational level. I propose that this mitigation value can be calculated by setting the aggregated amount of all mitigation efforts against the total amount of emissions allowed in order to reach the long-term global goal (LTGG) of the Agreement. From this calculation, all

[22] "Report of the High-Level Commission on Carbon Prices — Carbon ...." https://www.carbonpricingleadership.org/report-of-the-highlevel-commission-on-carbon-prices/. Accessed 21 Dec. 2018.
[23] "Leaders Set Landmark Global Goals for Pricing Carbon Pollution." 21 Apr. 2016, http://www.worldbank.org/en/news/press-release/2016/04/21/leaders-set-landmark-global-goals-for-pricing-carbon-pollution. Accessed 21 Dec. 2018.

trading coefficients, rates of exchange, & mitigation ratios can be calculated for existing pricing initiatives. This operation could be guided and facilitated by the Global Stocktake referred to in Article 14 of the Agreement.

Additionally, just as with misaligned prices, the varying scope and coverage of carbon pricing initiatives has created a lack of trust in market-based mechanisms such as the Joint Implementation (JI) and the Clean Development Mechanism (CDM). This skepticism stems from the difficulty to accurately track and verify mitigation efforts and the perverse incentives embedded in the framework of the mechanisms. Although market-based mechanisms are crucial instruments for achieving cost-effective mitigation, and when implemented correctly they can increase flexibility & remove barriers to scaling up mitigation ambition, the JI and CDM are plagued by a lack of trust due to their opaque and inefficient processes & methodologies for monitoring, reporting, verification, and issuance- especially with regards to establishing baselines and assessing the 'additionality' of GHG savings.[24]

As stated in a study commissioned by FOEN, “the key regarding acceptance of market mechanisms as an appropriate solution for climate change mitigation is trust that mechanisms can achieve environmentally credible mitigation while not jeopardizing interests of domestic industries that provide mitigation technologies.”[25] A properly designed market-based mechanism that significantly decreases the role of a centralized administrator by relying on a distributed

[24] "Tool for the demonstration and assessment of ... - CDM - unfccc." https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-01-v5.2.pdf/history_view. Accessed 21 Dec. 2018.
[25] "Market Mechanisms: Incentives and Integration in the ... - Climate Focus." 20 Nov. 2015, https://climatefocus.com/sites/default/files/Market%20Mechanisms%20Incentives%20and%20Integration%20in%20the%20Post%202020%20World.pdf. Accessed 21 Dec. 2018.

verification system for mitigation actions can achieve this increase in trust and can be a crucial instrument for linking carbon pricing initiatives and harnessing low-cost mitigation globally.

While the existence of current and proposed carbon pricing initiatives demonstrates positive steps forward, the fragmentation and heterogeneity of carbon pricing initiatives have caused several significant issues that need to be addressed to expand and accelerate the widespread adoption of mitigation efforts through pricing initiatives. As described above, the most notable issues are (1) the misalignment of pricing initiatives at the regional, national, and subnational level, (2) the lack of trust between Parties that mitigation outcomes are linked to mitigation actions, and (3) the lack of a clear framework for accounting and verification of mitigation outcomes that prevents double counting.

As also highlighted above, in addition to the pledges of nation states to manage The Commons, a highly diverse set of sub-national government entities (states, cities, and municipalities), private sector entities and industrial sectors (i.e. aviation industry) have also entered into comparable pledges to report and manage their use of The Commons. These different pledging systems currently co-exist alongside each other with a very low level of integration and interoperability and this issue has created a situation where the present-day global governance systems for greenhouse gas emissions reporting and management (including the operation of carbon markets) is severely fragmented, limited in coverage & scope, and thus has created friction that severely compromises the environmental integrity of global efforts to mitigate climate change involving double-counting, regulatory uncertainty, and free-rider problems.

The overall governance structure is in dire need of a transformation that appropriately addresses the fundamental differences in design, implementation, and standards of the diverse and heterogeneous climate action pledges and carbon pricing mechanisms in various jurisdictions. This fragmentation detracts from the effectiveness of global GHG governance systems, and without a mechanism that enables comparability, and thus fungibility, of mitigation outcomes across schemes and jurisdictions, our ability to effectively manage the Global Climate Commons remains severely limited.

Proposed Solution

In recognition of the fundamental differences in design, implementation, and standards of the diverse and heterogeneous climate action pledges and carbon pricing mechanisms, the UNFCCC, and Parties to the Agreement, through the Katowice Texts, have introduced a set of high-level guidelines to facilitate the development of the appropriate registry systems to create the comprehensive and transparent bottom-up framework called for in the Agreement. Following these guidelines, I propose a solution in the form of a public registry, monitoring platform, and mitigation value protocol, built on a distributed ledger (DLT) architecture, that accommodates the fundamental differences in design, implementation, and standards to facilitate the Monitoring, Reporting and Verification (MRV) of data for compiling greenhouse gas (GHG) inventories, as well as the generation, exchange, and ultimate termination of mitigation assets. The primary functions of the proposed registry system and monitoring platform will allow Parties to:

- Communicate Nationally Determined Contributions, and information necessary to track progress made in implementing and achieving its NDC, to the Secretariat, as called for in Article 4;
- Provably verify that mitigation outcomes align with mitigation actions;
- Establish Mitigation Values (MVs) for Regional, National, or Subnational initiatives that are consistent with achieving the long-term global goal (LTGG) of the Paris Climate Accord;
- Facilitate the generation and voluntary exchange international mitigation outcomes (ITMOs), or mitigation assets, to achieve Nationally Determined Contributions (NDCs), as called for in Article 6;
- Communicate a national inventory report of anthropogenic emissions by sources and removals by sinks of greenhouse gases, prepared using good practice methodologies accepted by the Intergovernmental Panel on Climate Change and agreed upon by the Conference of the Parties serving as the meeting of the Parties to this Agreement, as called for in Article 13;
- Assess the collective action of a Parties mitigation commitments, in relation to other Parties commitments, as called for in Article 14.

In short, I propose a DLT-based registry system and monitoring platform to fulfill the requirements of the provisions addressing the preparation and submission of Parties Nationally Determined Contributions (NDCs) outlined in Article 4; the provisions addressing the use of internationally transferred mitigation outcomes towards nationally determined contributions outlined in Article 6; the provisions addressing the preparation and submission of Parties plans

for implementation of adaptation actions outlined in Article 7; the provisions addressing the transparency framework for action and support outlined in Article 13; and the provisions addressing the ambition mechanism facilitated through the Global Stocktake outlined in Article 14.

The purpose of utilizing a distributed ledger architecture for this solution is primarily due to its ability to act as a tamper-proof form of record keeping, secured by cryptography, and maintained by a network of individual computers. Additionally, the economic model associated with DLT platforms aligns the private incentive for using a shared resource with maximizing the value of the shared resource for the community. A prime example of this is the mining fee awarded on the Ethereum blockchain for ensuring the validity of a transaction and thus protecting the integrity of the network.

These unique features provide us with the ability to reconfigure existing economic governance systems that account for environmental and social injustices, and allows us to make informed decisions for the good of people and the planet that address economic growth and human development in a smart and coordinated manner, potentially removing the “tragic” element of managing the global climate commons.

It is my hypothesis that using DLT to implement a governance process and mechanism for the reporting of NDCs, Adaptation actions, GHG inventories, and mitigation assets (ITMOs) - on various levels of aggregation - and a governance process and mechanism to manage the allocation of rights and obligations of use, can dramatically improve the effectiveness of The Commons governance systems.

Such a system could also automate bilateral & multilateral arrangements by utilizing smart contracts, allowing for a much greater diversity of contract types, market structures, and more equitable approaches to economic activity.

In fact, all of the existing systems required for the reporting of GHG inventories and the system to manage the allocation of rights and obligations of use are highly vertically interconnected, yet these systems co-exist alongside each other with a very low level of horizontal integration and interoperability (cross-domain & scope), and therefore would be much more efficient if built on complementary infrastructure. Implementing a solution for interconnection would achieve the following:

- Full integration of different pledging systems for mitigation actions across all pledging entities, thus allowing for strong decentralization of participation in governance;
- Accelerate the process by which GHG inventories are being prepared, thus providing a real dashboard to measure the effectiveness of policies and measures taken at various levels of government;
- Increase the feasibility of making mitigation claims for small, distributed actions;
- Enhance the transparency and trust in the GHG governance system;
- Reduce, by a order of magnitude, the costs of being able to make mitigation claims (i.e. the verification process for mitigation assets), thus providing additional incentives to invest in mitigation, and facilitating the cooperation between entities to implement and benefit from multilateral mitigation actions.

Concretely, and within the context of the global GHG management governance systems, I posit that a DLT architecture possesses the ability to resolve the interoperability design problems associated with different climate action pledges and carbon pricing mechanisms of varying scope & design, such as national Emission Trading Schemes (ETS), Nationally Determined Contributions (NDCs), the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), the voluntary targets of sub-national public entities (Non-State Actors), and the science-based (Voluntary) targets of the private sector.

Chiefly, I envision a layered DLT architecture that accommodates the fundamental differences in design, implementation, and standards of the diverse and heterogeneous climate action pledges and carbon pricing mechanisms in various jurisdictions that will facilitate the Monitoring, Reporting and Verification (MRV) of data for compiling greenhouse gas (GHG) inventories and the generation of mitigation assets. By utilizing this integrated architecture, I firmly believe I could provide carbon market participants the ability to ensure the veracity of data inputs (Layer 1), deliver verified GHG inventory data to distributed registry accounts (Layer 2), and convert verified GHG inventory data, in accordance with a range of protocols, into verified transferable mitigation assets (Layer 3).

In concrete terms, I am proposing to develop an architecture that upgrades the existing rules, methodologies, and procedures for the implementation of GHG inventories and carbon credit origination. I intend to build a solution that would implement a layered DLT architecture for all mitigation action project types in coordination with the appropriate implementation partners. Once again, the functions of the layers are to (Layer 1) ensure the veracity of data inputs, (Layer 2) deliver verified GHG inventory data to registry accounts, and (Layer 3) convert

verified GHG inventory data, in accordance with a range of protocols, into verified transferable mitigation assets.

I currently envision this market-based mechanism, that relies on distributed verification, taking the form of a bounty network and delegated democracy system, where mitigation asset generators post bounties for technically competent 'agents' to verify the 'additionality' of mitigation actions, with ultimate judgment rendered through delegated voting (PLCR) according to one's assessment of the mitigation action in question.[26][27] In the event of a dispute, I plan to utilize an arbitration system, such as OpenCourt or Kleros.[28][29] For the transaction settlement layer, we will utilize a consensus algorithm with a relatively strong focus on accountability, such as Tendermint or Proof-of-Authority.[30][31] Additionally, for the formation of the intangible digital assets that represent mitigation outcomes, I plan to utilize a smart contract structure akin to the non-fungible standards of ERC-721 or ERC-998.[32][33]

It's important to make note of the reason for using these smart contract structures. Essentially, in order to solve for the interoperability design problems associated with different climate action pledges and carbon pricing mechanisms of varying scope & design, a composable asset structure must be utilized, and the immutable storage of an asset's history, from genesis to

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[26] "List of DOEs - CDM - unfccc." https://cdm.unfccc.int/DOE/list/index.html. Accessed 21 Dec. 2018.
[27] "GitHub - ConsenSys/PLCRVoting: Partial Lock Commit Reveal Voting ...." https://github.com/ConsenSys/PLCRVoting. Accessed 21 Dec. 2018.
[28] "OpenCourt: Legally Enforceable Blockchain-Based Arbitration." 18 Oct. 2018, https://media.consensys.net/opencourt-legally-enforceable-blockchain-based-arbitration-3d7147dbb56f. Accessed 21 Dec. 2018.
[29] "Kleros." https://kleros.io/. Accessed 21 Dec. 2018.
[30] "Tendermint: Blockchain Consensus." https://tendermint.com/. Accessed 21 Dec. 2018.
[31] "Proof-of-Authority Chains · Parity Tech Documentation." https://wiki.parity.io/Proof-of-Authority-Chains. Accessed 21 Dec. 2018.
[32] "ERC-721." http://erc721.org/. Accessed 21 Dec. 2018.
[33] "ERC-998 Composable Non-Fungible Token Standard · Issue ... - GitHub." https://github.com/ethereum/EIPs/issues/998. Accessed 21 Dec. 2018.

present day, is a necessary component of any digital intangible assets, especially ITMOs. This information must also be transparent and immediately traceable. By utilizing a smart contract structure akin to ERC-721 or ERC-998, I envision the registry and platform being able to fulfill the functions required by the UNFCCC in the Katowice Texts, regarding the tracking and identification of ITMOs, including the:

- Creation of ITMOs;
- First transfer of ITMOs;
- Transfer of ITMOs;
- Acquisition of ITMOs;
- Holding of ITMOs;
- Cancellation of ITMOs;
- Use of ITMOs;
- Voluntary cancellation of ITMOs;
- Voluntary cancellation for an overall mitigation in global emissions;
- [Transfer of ITMOs for the share of proceeds for adaptation.]

With regards to mitigation asset values, I envision them being calculated through a series of steps, starting first with the aggregating & indexing the collective mitigation actions of all Parties to the Agreement. The amount of collective mitigation actions is measured in tons of carbon dioxide equivalent (tCO2e), and the measure of each specific GHG in tons of carbon dioxide equivalent (tCO2e) is calculated according to the global warming potential values from

the IPCC's Fifth Assessment Report (AR5 GWP-100).[34] The next step is to set the amount derived from this 'aggregating & indexing' approach against the carbon budget.[35] By aggregating & indexing the total amount of intended commitments, and by setting that amount against the total carbon allowance, we establish the boundaries needed to accurately calculate a mitigation value for one ton of mitigation action. The last step is to take the inverse of the differential between the aggregated total of commitments and the total carbon allowance. By taking the inverse of the differential, we establish a unified price that increases as the differential between the boundaries increases, meaning that Parties are incentivized to strengthen commitments and widen the differential to cause the unified price to appreciate.

Apart from the functions listed above, this unified price acts as the pricing signal needed to determine the various trading coefficients between mitigation assets from different jurisdictions and pricing initiatives. This unified price can also be used as a baseline for developing marginal abatement cost curves (MACC) and as a specific input for integrated assessment models, such as William Nordhaus' DICE Model.[3637] The value of one ton of mitigation action can be represented by one mitigation unit, which can be the transactional unit used on the platform for the voluntary exchange of international mitigation outcomes across jurisdictions and pricing initiatives.

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[34] "Global Warming Potential Values - GHG Protocol." https://www.ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf. Accessed 21 Dec. 2018.
[35] "Remaining carbon budget - Mercator Research Institute on Global ...." https://www.mcc-berlin.net/en/research/co2-budget.html. Accessed 21 Dec. 2018.
[36] "Marginal abatement cost - Wikipedia." https://en.wikipedia.org/wiki/Marginal_abatement_cost. Accessed 21 Dec. 2018.
[37] "DICE/RICE models - William Nordhaus | Yale Economics - Google Sites." 9 Oct. 2017, https://sites.google.com/site/williamdnordhaus/dice-rice. Accessed 21 Dec. 2018.

Additionally, taking into consideration that Parties may wish to record specific commitments or actions apart from the platform itself, I envision a core piece of platform functionality being the conversion of Excel tabular data to link to blockchain frameworks, as pioneered by the Clean Energy Blockchain Network with Hyperledger Fabric.[38]

Furthermore, to assist in aiding the most vulnerable countries from the negative impacts of Climate Change, I envision the platform to facilitate the distribution of Results-Based Climate Finance (RBCF) through an amendable smart contract structure.[39] RBCF is a form of climate finance where funds are disbursed by the provider of climate finance to the recipient upon achieving a pre-agreed set of climate-related results. RBFC explicitly links financing to results, thereby "shifting the financial risk of nondelivery (of results) from the funder to the recipient." These results generally refer to outputs, outcomes, and/or impacts, which are translated into measurable Disbursement-Linked Indicators (DLIs), which means that RBCF can support the development of mitigation assets & outcomes.[40]

Since 2011 governments have only allocated approximately $9.9 billion USD to the Green Climate Fund (GCF) to drive the investment required to facilitate transformational change toward low-carbon development.[41] Additionally, a provision of the Paris Agreement "strongly urges developed country Parties to scale up their level of financial support, with a concrete roadmap to achieve the goal of jointly providing $100 billion USD annually by 2020" to help

[38] "Power Ledger & Clean Energy Blockchain Network Partner With ...." 1 May. 2018, https://medium.com/power-ledger/power-ledger-clean-energy-blockchain-network-partner-with-northwestern-university-for-first-7daca76914b6. Accessed 21 Dec. 2018.
[39] "Results-Based Climate Finance in Practice - World Bank Documents ...." 18 May. 2017, http://documents.worldbank.org/curated/en/410371494873772578/pdf/115053-WP-PUBLIC-111p-RBCFinPracticeFinalMay.pdf. Accessed 21 Dec. 2018.
[40] "dlis and disbursement arrangements - Policies and Procedures." 18 Jun. 2012, https://policies.worldbank.org/sites/ppf3/PPFDocuments/090224b08234146d.pdf. Accessed 21 Dec. 2018.
[41] "Green Climate Fund." https://www.greenclimate.fund/. Accessed 21 Dec. 2018.

developing countries switch from high-carbon to low-carbon economies and adapt to the adverse effects of Climate Change.[42] By providing an amendable RBCF smart contract for the efficient allocation of financial flows to RBCF programs, I envision the platform assisting in achieving the commitments made by developed country Parties to provide $100 billion a year by 2020 for mitigation and adaptation.

Lastly, by relying on distributed verification, this integrated architecture significantly decreases the role of a centralized administrator and can be a crucial instrument for driving substantial time & monetary efficiency gains associated with the MRV actions required, thus assisting in linking climate action pledges and carbon pricing mechanisms to harness low-cost mitigation globally.

Conclusion

In recognition that carbon pricing initiatives suffer from fragmentation, deficient verification mechanisms, and inadequate valuation conventions for cross-initiative exchange, I propose a solution in the form of a public registry, monitoring platform, and mitigation value protocol, built on a distributed ledger (DLT) architecture, that accommodates the fundamental differences in design, implementation, and standards to facilitate the Monitoring, Reporting and Verification (MRV) of data for compiling greenhouse gas (GHG) inventories, as well as the generation, exchange, and ultimate termination of mitigation assets.

As Scott Barrett, Lenfest-Earth Institute Professor of Natural Resource Economics at Columbia University, recently stated at a panel discussion on the future of international climate negotiations: “Enforcement is the essential part of addressing collective action. International

[42] "Report of the Conference of the Parties on its twenty-first ... - unfccc." 29 Jan. 2016, https://unfccc.int/resource/docs/2015/cop21/eng/10a01.pdf. Accessed 21 Dec. 2018.

systems are bad at voluntary cooperation without strong enforcement, and are good at coordinating activities for mutual gain."[43] The distributed and immutable nature of distributed ledger technology allows us to programmatically encode operational features of enforcement into systems, therefore endowing us with the ability to voluntarily coordinate action to achieve collective goals.

The solution I propose in this paper provides a comprehensive view of how the collective action of all individual NDC's stack-up in relation to the long-term global goal (LTGG) of the Paris Agreement, and acts as a guiding instrument for future policy formation. Additionally, by incentivizing technically competent 'agents' to verify mitigation actions, the platforms distributed market-based mechanism for verification solves the issue of provably verifying that mitigation outcomes align with mitigation actions. Lastly, by establishing a unified price for mitigation assets through the aggregating and indexing approach proposed, the mitigation value protocol combats the issues plaguing existing pricing initiatives by linking regional, national, and subnational pricing initiatives. The public registry and monitoring platform I envision equips Parties of the Agreement with the tools needed to ensure that individual actions, and therefore the collective action of all Parties, align with achieving the long-term global goal (LTGG) of the Paris Climate Accord.

[43] "Where Next on Climate? The Future of the International Climate ...." https://energypolicy.columbia.edu/where-next-climate-future-international-climate-negotiations. Accessed 21 Dec. 2018.

Appendix

Additional resources and readings can be found here.