Received: 3 March 2023 | Revised: 9 May 2023 | Accepted: 12 May 2023 | Published online: 17 May 2023

RESEARCH ARTICLE

Green and Low-Carbon Economy
2023, Vol. 00(00) 1–14
DOI: 10.47852/bonviewGLCE3202825

BON VIEW PUBLISHING

A Blockchain Cross-Border Payment System to Enable a Potential Caribbean Regional Emissions Trading Scheme

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Abstract: The implementation of the Nationally Determined Contributions (NDCs) is crucial for achieving the goals of the Paris Agreement. However, the lack of financial support from the international community has been a significant obstacle for the Caribbean Community Member States. To this end, market-based mechanisms, such as an emissions trading scheme (ETS), included in the Paris Agreement can provide an effective incentive for greenhouse gas-emitting stakeholders to reduce their emissions and help countries achieve their NDCs. A cross-border payment system is essential for the transfer of funds as well as emissions allowances between regulated entities in different countries in a regional ETS. The cross-border payment system needs to be secure, fast, efficient, and cost-effective. Notably, the Caribbean region's current cross-border payment system is based on correspondent banking and ill-equipped to properly handle cross-country trading in a potential regional ETS. As a result, blockchain emerges as a practical tool to strengthen the Caribbean's cross-border payment system to facilitate regional emissions trading. This study explores how a blockchain cross-border payment system can be used for a potential Caribbean ETS.

Keywords: blockchain, cross-border payments, emissions trading scheme, Caribbean Community (CARICOM)

1. Introduction

Early international cooperation for climate action can be traced to 1992 at the Earth Summit in Rio de Janeiro, where countries met to discuss the climate change problem and to propose a mechanism to collectively stabilize greenhouse gas (GHG) concentrations in the atmosphere. This led to the formation of the United Nations Framework Convention on Climate Change (UNFCCC), an international body dedicated to combating climate change. The next major milestone occurred 5 years later as Parties agreed to the Kyoto Protocol, the first international treaty that committed countries to pursue GHG emission reduction action [1].

Embedded in the Kyoto Protocol was the principle of common but different responsibility, which recognizes that while all countries have a responsibility to address climate change, developed and developing countries have different capabilities and historical responsibilities for GHG emissions, and therefore, should have different roles and responsibilities in addressing climate change. This led to the Annex Classification framework, in which 38 developed countries were classified as Annex I and had GHG emission reduction commitments. The remaining Parties to the Kyoto Protocol were classified as non-Annex I and were waived from emission reduction commitments [2].

The different responsibilities from the Annex Classification eventually became a problem as it did not anticipate the emergence of newly industrialized countries, such as China, India, and Brazil, which became major emitters of GHGs. However, these countries were classified as non-Annex I and had no legally binding GHG emission reduction commitments. In contrast, several developed countries that compete against the newly industrialized countries in international trade had GHG emission reduction commitments [3].

These problems eventually led to a deadlock in international climate negotiations, as when the Kyoto Protocol's first commitment period expired in 2012, many developing countries were reluctant to agree to a new climate agreement that did not adequately address their concerns about the Annex Classification. The Paris Agreement, which was adopted in 2015, addressed some of these concerns by introducing the framework for the Nationally Determined Contributions (NDCs). The NDCs are voluntary climate action plans, determined by each country based on their specific circumstances and capabilities. The NDCs outline each Party's pledge to reduce GHG emissions in specific sectors [4].

To ensure that there is enhanced climate action over time, the Paris Agreement includes a provision called the Global Stocktake. The Global Stocktake is an international assessment that is designed to evaluate the Parties' achievement of their NDC targets, as well as identify gaps and areas for improvement in the implementation of the Paris Agreement [4].

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The Member States of the Caribbean Community (CARICOM) also submitted their Intended Nationally Determined Contributions[1] to the UNFCCC for the Paris Agreement. Some of their NDCs were conditional upon the receipt of technical and financial support from the international community. Unfortunately, financial support for the NDCs has not been forthcoming to the CARICOM Member States' expectations.

Fortunately, the Paris Agreement includes flexible market-based mechanisms to encourage the implementation of Parties' NDCs. More specifically, it includes the emissions trading system, which incentivizes GHG-emitting stakeholders in countries to reduce their emissions. This is done by the state setting a limit on the amount of emissions that stakeholders can produce and allowing the trading of emission allowances to facilitate compliance. The CARICOM Member States can adopt an emissions trading scheme (ETS) to help them implement their NDCs.

A core component of a potential regional would involve the sale and transfer of emission allowance across participating countries. A cross-border payment system is essential for such transactions. However, from 2015 to 2018 the Caribbean region experienced problems of derisking and the loss of correspondent banking relationships, which in turn negatively affected its cross-border payment system [5–7]. While some banks in the region have obtained replacement correspondent banks, the recent challenge highlights the vulnerability of the current cross-border payment system. There is a need for a better cross-border payment system.

In this regard, blockchain emerges as a possible solution. Blockchain is a decentralized digital ledger technology that allows for secure and transparent record keeping of transactions. Blockchain can be leveraged in a cross-border payment system to facilitate international money transfers. Such a system allows for faster, cheaper, and more secure cross-border transactions compared to the traditional correspondent banking cross-border payment system.

The objective of this study is to explore how a blockchain cross-border payment system can be used for a potential Caribbean ETS.[2]

The sub-objectives are to:

1) Assess the Caribbean progress in mobilizing finance to implement their NDCs;
2) Review the Caribbean current cross-border payment system;
3) Explore the mechanics of a blockchain cross-border payment system for a potential Caribbean regional ETS;

[1]Upon the ratification of the Paris Agreement, Parties INDCs became their NDCs. Only Belize submitted a modification of its INDC to become its NDC. All other CARICOM Member States submitted identical copies of their INDC to become NDCs [8].

[2]Due to the weak progress in implementing the NDCs, the CARICOM Member States can look toward a regional emissions trading scheme as a market-based mechanism to help them implement their NDCs. The regional ETS would involve the buying and selling of emissions allowances across borders. However, the current cross-border payment system based on correspondent banking and SWIFT is flawed and inefficient. It would take too long for transactions to settle, which can result in Herstatt's risk. Therefore, there would be a need for a better cross-border payment system if a regional ETS is created. Subsequently, this study proposes a block-chain cross-border payment system to be used for the regional ETS.

Notably, the novelty of this paper resides in the idea of the application of blockchain for cross-border payments on an ETS. Presently, Ripple uses blockchain to facilitate cross-border payments. Additionally, the European Union (EU) ETS, and the Regional Greenhouse Gas Initiative (RGGI) are two regional ETS. However, there is no ETS that applies blockchain. Therefore, this study contributes to the literature.

The remainder of this study is structured as follows. Section 2 reviews the Caribbean's progress in implementing their NDCs. Section 3 explores the mechanics of a potential ETS for the Caribbean. This ETS can help the countries achieve their NDCs. Section 4 assesses the current cross-border payment system. Section 5 provides a literature review on blockchain. Section 6 provides recommendations for the development of the blockchain cross-border payment system for the regional ETS. Section 7 concludes this study.

2. Climate Change in the Caribbean and the NDCs

The CARICOM Member States' NDCs are diverse. This diversity is a reflection of the complex and multifaceted nature of the climate change challenge in the region. It also underscores the need for tailored and context-specific approaches to climate action that take into account the unique circumstances and priorities of each country. Table 1 [9] provides an overview of their NDCs.

Estimates from eight Caribbean countries indicate that the total cost of mitigation in their NDCs is US$23.1 billion. Estimates from five countries reveal that the total adaptation cost of their NDCs is US$28 billion. The combined cost of these estimates over the 2020–2030 period is US$51.3 billion, which represents approximately 40% of the Caribbean region's GDP in 2021. In comparison, the Caribbean region received US$1,330 million in international climate finance, of which 62% were grants and 38% were loans. Subsequently, climate finance significantly falls short of the Caribbean's NDC needs [10]. Table 2 [10] provides a summary.

A few countries, namely the Bahamas, Dominica, Grenada, St. Lucia, and St. Vincent and the Grenadines, express their intention to use public funds to help finance their NDC targets. The majority of Caribbean countries indicate their intent to rely heavily on international finance to fund their NDC implementation. The Green Climate Fund was the most common funding source identified. This was followed by the Climate Investment Funds and then the Global Environmental Facility [10].

The intention for the CARICOM Member States to tap into the international climate funds is ambitious, and international climate finance funds are difficult for small island developing states (SIDS) to access. This is due to stringent accreditation criteria that require organizations to meet high standards of governance, financial management, and project implementation. Furthermore, the accreditation process can be complex and involve multiple steps and requirements, including submitting detailed financial and project reports, undergoing due diligence checks, and meeting with accreditation panels. SIDS often lack the necessary institutional capacity and expertise to meet these criteria, making it challenging for them to become accredited.

3. Potential Cross-Border Payment Issues for the Caribbean ETS

An ETS will not provide grant or loan funding to address the funding gap for the NDCs. Rather, it is a market-based

Table 1
CARICOM Member States' NDCs

Country	Emission reduction target	RE target	EE target	NDC tools	Primary sectors
Antigua and Barbuda		(1) By 2030, achieve an energy matrix with 50 MW of electricity from RE, (2) by 2030, produce 100% of electricity demand for water sources from off-grid RE		Conditional: (1) by 2020, establish EE standards for the import of vehicles and (2) construct a WTE plant by 2025. Unconditional: (1) create a legal/policy framework for low carbon development and (2) update building codes	Energy, health, tourism, agriculture, waste, water, transportation, and forestry
The Bahamas	Conditional: 30% of 2030 BaU	(1) 30% of RE in the energy mix by 2030		(1) Create a legal/policy framework for RE, (2) PPP for RE, (3) lower import duty on hybrid cars, (4) establish an EE building code, (5) tax vehicle imports based on fuel consumption and engine CC, and (6) establish a National Forestry Estate	Energy, forestry, and transport
Barbados	Conditional: 30% of BaU by 2030	RE to produce 65% of peak demand by 2030	(1) 22% reduction in BaU by 2029, (2) in non-electricity, a 22% reduction in BaU by 2029	(1) Tax incentives to encourage the import of hybrid vehicles	Energy, industry, waste, and agriculture
Belize	Conditional: 20% reduction in transport fuel use	Increase RE to 85% of the energy mix by 2030		(1) Protect forests, (2) reduce wood fuel consumption, (3) protect mangroves, (4) develop transport policy, (5) develop a sustainable energy action plan, (6) promote EE, and (7) develop solid waste policy	Energy, solid waste management, and transport
Dominica	Conditional: 44.7% of 2014 emissions reduction by 2030	(1) Geothermal power generation: 39.3 Gg, (2) solar PV for hotel sector: 0.24 Gg, (3) solar PV for schools, universities, hospitals, etc.: 0.86 Gg, (4) off-grid RE backup for Ross University: 1.71 Gg, (5) promoting hybrid vehicles: 12 Gg, (6) RE-powered mini-grids: 2.92 Gg, (7) reduce CH4 emissions from landfill: >11 Gg	5.2 Gg from streetlights	(1) RE investment in geothermal, solar PV, off-grid micro-hydro, and wind, (2) replace all Govt. vehicles with hybrids, (3) policy to encourage the import of hybrids, (4) replacing streetlights in Portsmouth with LED fixtures, (5) implement an EE retrofits program, (6) develop an EE building code, and (7) implement an educational awareness program	Energy, transport, manufacturing, construction, residential, agriculture, fisheries, forestry, and solid waste
Grenada	Conditional: 30% of 2010 emission reduction by 2030	(1) 10 MW solar, 15 MW geothermal, 2 MW wind by 2025, (2) landfill CH4 capture	(1) Building retrofits (20% reduction), (2) building codes (30% reduction), (3) EE in hotels (20% reduction)	(1) Building codes, (2) transport fuel tax, and (3) EE standards	Electricity, transport, waste, and forestry

(*Continued*)

Table 1
(*Continued***)**

Country	Emission reduction target	RE target	EE target	NDC tools	Primary sectors
Guyana	Conditional: (1) avoid deforestation: 48.7 Mt CO_2; (2) energy: 100% renewable power supply by 2025	Conditional: energy: 100% renewable power supply by 2025		(1) Forestry policies, (2) building codes, (3) net metering, (4) remove import duty on RE equipment, (5) conduct energy audits, (6) public education, and (7) RE for new townships	Energy and forestry
Haiti	Conditional: 26% of BaU by 2030; Unconditional: 5% of BaU by 2030	Conditional: 60 MW hydro (24.5%), 50 MW wind (9.4%), 30 MW solar (7.5%), and 20 MW biomass (5.6%)	Reduce fuelwood consumption by 32% by 2030, (2) distribution of 1M low-consumption lamps		Energy, agriculture, forestry, land, and waste
Jamaica	10% of BaU by 2030	Increase RE to 20% of the energy mix by 2030		(1) Implement climate change policy, (2) implement energy policy, and (3) scale up RE	Energy and transport
St. Kitts and Nevis	Conditional: 35% of BaU by 2030	35 MW geothermal, 1.9 MW solar, 7.6 MW wind, and 0.5 MW WtE	(1) Reduce electricity losses by at least 50%, (2) 5% reduction in national energy consumption, and (3) a 5% reduction in fuel consumption		Electricity and transport
St. Lucia	Conditional: 23% of BaU by 2030	35% of the energy generated using RE by 2025 and 50% by 2050		(1) Implement EE buildings and (2) improve EE in transport	Energy and transport
St. Vincent and the Grenadines	22% of BaU by 2025	50% of the energy supply from geothermal	22% reduction in electricity consumption compared to the BaU by 2025	(1) New building code, (2) reduce import duties on low-emission vehicles, and (3) labeling of appliances	Energy, industry, agriculture, and waste
Suriname		(1) 168 MW hydropower plant, (2) 62 MW from geothermal, (3) a biofuel project to blend ethanol in gasoline, (4) 25% RE generation by 2025		Policy/and laws	Energy and forestry
T&T	15% of BaU by 2030			(1) 15% reduction of BaU in the three priority sectors, (2) implement a forestry policy, (3) implement an environmental policy, (4) implement a climate policy, and (5) consider RE projects	Conditional: power and industry, Unconditional: Transport

Note: T&T has a renewable energy target of 10% of total electricity by 2021. However, this was not expressed as an INDC or NDC.

Table 2
Needs estimates of Caribbean NDCs 2015 – 2030 (million USD)

Country	Mitigation	Adaptation	Total	Total cost/GDP	Total average cost/capita	Receipt of finance
Antigua and Barbuda	200	200	400	29%	4,085	15.8
Bahamas						
Barbados						0.02
Belize	200		200	12%	503	19.5
Cuba						65.1
Dominica	100	25	125	24%	1,736	31.9
Dominican Republic	8,900	8,600	17,500	22%	1,613	499
Grenada				19%	1,778	1.6
Guyana		1,600	1,600	29%	2,034	391
Haiti	8,800	16,600	25,400	175%	2,228	162.4
Jamaica						62.5
St. Kitts and Nevis						0.1
St. Lucia	400		400	25%	2,178	36.7
SVG						15.2
Suriname	2,500	1,000	3,500	122%	5,966	28.7
T&T	2,000		2,000	10%	1,429	0.1
Total	23,100	28,025	51,125	40%	1,983	1,330

mechanism that is designed to stimulate GHG emission reduction action by the private sector.[3]

First, a distinction must be made between a mandatory ETS and a voluntary ETS.

In a mandatory ETS, a government may create a regulatory agency to operate the exchange.[4] The government and the ETS regulator collaborate to create a cap on the amount of GHG emissions that certain sectors are allowed to produce. The government in collaboration with the ETS regulator would then indicate which GHG-emitting private sector companies would be required to participate in the ETS. Private sector companies that are required to participate in the ETS are referred to as regulated entities.

The regulated entities are assigned limits on their emissions, and then there are given emissions allowances to cover their emissions. Each emissions allowance gives the regulated entity a right to emit 1 ton of carbon dioxide equivalent (CO_2-eq) of GHG. Most likely at the start of the ETS, the regulated entities are given emissions allowances based on their historical emissions, a process known as grandfathering.

At the end of the year or period specified by the ETS regulator, the regulated entities are required to surrender emissions allowances to cover their GHG emissions. If a regulated entity has more emissions than what can be covered by its emissions allowances, it can face some form of penalty from the ETS regulator. This penalty can be a fine for non-compliance, but it can also include softer penalties such as the reduction in the emission allowances given to the regulated entity in the next year. Since the regulated entity would not desire to face any penalty, it would be incentivized to reduce its emissions. However, some regulated entities would be more efficient in reducing their emissions than others and thus would have surplus emissions allowances. Given this, the ETS regulator allows the trading of emissions allowances. Therefore, the most efficient regulated entities can capture a financial incentive as they can sell their surplus emissions allowances on the ETS market. In comparison, the less efficient regulated entities can purchase extra emissions allowances to cover their emissions. Thus, the mandatory ETS creates a system that encourages the reduction of emissions by the most efficient regulated entities, and it encourages the least efficient regulated entities to financially compensate their efficient peers as they purchase emissions allowances. The ETS helps the efficient and inefficient producers to collectively reduce the emissions in sectors and help countries achieve the NDC goals.

In a voluntary ETS, there is no cap on emissions set by a regulator agency, and GHG-emitting private sector companies are not mandated to participate. Additionally, there are no penalties for non-compliance. Instead, some companies may voluntarily participate by voluntarily reducing their GHG emissions. Participation in a voluntary ETS is often done for good public relations and to boost a company's corporate image.

Notably, the CARICOM Member States' NDCs did not specify an ETS as a tool to help them achieve their GHG emission reduction targets. Nevertheless, an ETS provides an economic incentive for companies to reduce their emissions as it essentially puts a price on the GHG emissions, and it encourages companies to seek the most cost-effective way to reduce their emissions.

A regional mandatory ETS for the Caribbean can act as a tool to stimulate GHG emission reduction action. To function, an ETS must have several components.

3.1. Emissions cap, GHGs, and sectors

First, there must be a limit on the emissions. The countries considering participating in the ETS will have national objectives for the reduction of their GHG emissions to achieve their NDC commitments to the Paris Agreement. Moreover, each country's NDCs would specify which sectors would be targeted for GHG

[3]No Caribbean country has identified an ETS as a tool to help them implement their NDCs. This is due to the ad hoc nature of the NDCs. Caribbean governments use the language of conditional NDCs, which means they will implement the NDCs if they receive support. If they do not receive support, they may not implement their NDCs. Waiting for international support to implement the NDCs is almost like "Waiting for Godot," as in the book by Samuel Beckett, in which Godot never came.

Although NDCs are voluntary, countries are expected to take action to reduce their emissions. Furthermore, after every Global Stocktake, there will be an expectation for countries to take enhanced action to reduce their GHG emissions. Therefore, the Caribbean will face peer pressure to pursue action to implement their NDCs and reduce their emissions. An ETS is a tool that can help the Caribbean implement their NDCs as it creates an economic framework to encourage GHG-emitting companies to reduce their emissions.

[4]This institution can be referred to as the ETS regulator.

emissions reduction. The participating countries' NDCs can inform the sectors, the GHGs, and the size of the emissions cap for the regional mandatory ETS.

Another relevant issue is the external margins. The external margin of an ETS refers to the boundaries of the scheme. In other words, it refers to the emissions sources or sectors that are not subject to the ETS and therefore do not need to acquire emission allowances or credits. For the Caribbean ETS, the GHGs and sectors not identified as target areas for action will form the external margin.

3.2. Distribution of emissions allowances

The second component is the system for the distribution of emissions allowances. The emissions allowances can be distributed for free or auctioned off at a fee. Regulated entities may desire the emission allocations to be allocated for free. However, free allocation can also result in windfall profits for polluters. Auctioning allowances can generate revenue for the ETS regulator, which can be used to offset its operational costs so that it would not be dependent on subsidies from any Caribbean government.

3.3. Trading of emissions allowances

The third component is the framework for the trading of emissions allowances. Regulated entities with surplus emissions allowances should be allowed to sell them on the ETS market. A distinction can be made between the types of markets: the primary market and the secondary market. In the primary market, emissions allowances are issued for the first time. In other words, the ETS regulator issues the emissions allowances to the targeted entities on the primary market. The secondary market, on the other hand, is where previously issued emissions allowances are traded. This market is used for trading between entities that have excess allowances and those that need additional allowances.

There are also variants for the trading of emissions on the secondary market, including exchange-based trading and over-the-counter (OTC) trading. Exchange-based trading involves the use of a centralized exchange, where buyers and sellers can trade emissions allowances. The exchange acts as a market maker, matching buyers and sellers and providing a transparent price discovery mechanism. There is a regulatory body that oversees the exchange. This regulator for the exchange ETS is referred to as the ETS regulator. Exchange-based trading is highly standardized, which helps to ensure that allowances are fungible and tradable. However, exchange-based trading can be subject to market volatility and liquidity issues, which can affect the price of emissions allowances.

OTC trading involves the direct negotiation between buyers and sellers, outside of a centralized exchange. OTC trading can be more flexible than exchange-based trading, as buyers and sellers can negotiate customized terms and conditions. However, OTC trading can be less transparent than exchange-based trading, and there is a risk of counterparty default. Due to the risk of the lack of transparency, an exchange is the better approach to facilitate emissions trading. Therefore, an exchange is recommended as a potential regional ETS for the Caribbean.

Designing the trading framework also involves establishing the rules and regulations for regulated emissions allowances. The rules should be clear and transparent and should provide a level playing field for all participants. These rules can include the minimum and maximum prices for emissions allowances, the frequency of auctions or trading periods, and the eligibility criteria for participating in the trading system. The design of the trading framework should also consider the potential for market power and market manipulation by large emitters. To prevent market manipulation, regulatory bodies can set limits on the percentage of emissions allowances that any one entity can hold or require regular disclosure of emissions data.

3.4. Demand and supply, price, penalty, and market stability reserve

Since the emission allowances will be traded in a liberalized market, then, the demand and supply of the emissions allowances will determine their price. The supply of emissions allowances will be affected by the volume of emissions allowances issued. If too many emissions allowances are issued, then there can be an oversupply on the secondary market, which can place pressure for the suppression of the emission allowances price. The experience of the EU ETS demonstrates that a low price and high supply undermine the effectiveness of an ETS as regulated entities can easily purchase emission allowances at a low price, thus removing the incentive to reduce emissions [11].

The experience of the EU ETS also indicates that a low price and excess supply can be corrected through the introduction of a market stability reserve (MSR) [11]. The MSR operates by adjusting the supply of allowances. If there is an oversupply and the price is too low, the MSR can remove a proportion of the excess allowances from the market or remove some of the new emissions allowances that were scheduled to be distributed in the primary market. The reduction of supply helps supports the emissions allowances price.

The demand for emissions allowances would be affected by the penalty for non-compliance. If there is a high fee for non-compliance, the regulated entities would be incentivized to purchase extra emissions allowances if they do not have sufficient to cover their emissions. However, care has to be taken to ensure that the non-compliance penalty fee is not high as it may discourage investment in heavy industry manufacturing sectors, which tend to be among the highest GHG-emitting sectors.

3.5. Regional or national

An ETS can be implemented at the national scale or a regional scale. A national ETS is an ETS that is implemented at the national level. It applies to all regulated entities across a country, and it allows the emissions allowances to be traded nationally.[5] In comparison, a regional ETS applies to a region. In the case of the EU ETS, it applies to all the regulated entities in the participating EU Member States. In the case of the RGGI, it is applied to different states in the USA.

1) EU ETS

The first ETS implemented was the EU ETS in 2005. Its implementation was conducted over multiple stages, including Phase I (2005–2007), Phase II (2008–2012), Phase III (2013–2020), and Phase IV (2021–2030).

Phase I involved private sector companies in the power and heavy industrial sectors were assigned caps on carbon dioxide emissions. The companies were freely given emissions allowances on the primary market based on grandfathering. The emissions allowances were tradable on the secondary

[5]Mexico implemented a pilot ETS in January 2020. This ETS can be considered a pilot of a national ETS as it applied only to one country/state. The ETS covers online carbon dioxide emissions from the energy and industry sectors. Therefore, the regulated entities were private sector companies from the energy and industry sectors producing least 100,000 tCO_2 per year [12].

market. A monitoring, reporting, and verification (MRV) system was introduced to track the emissions and companies' compliance. Companies found with more emissions than what they could cover with the emissions allowances were liable to pay a fine of €40 per ton of CO_2-eq [13].

Phase II was marked by an oversupply of emissions allowances, which caused low prices. The EU also allowed up to 10% of the total emissions allowances to be issued through auctions. However, this and the reduction in the cap by 6.5% were insufficient to trigger the rebound in prices. Other major developments include (*i*) the inclusion of nitrous oxide as a GHG for the emissions cap by some countries; (*ii*) the aviation sector was included in the ETS; (*iii*) Iceland, Liechtenstein, and Norway joined the EU ETS; (*iv*) regulated entities were allowed to cover their emissions by purchasing foreign carbon credits; and (*v*) the penalty for non-compliance was increased to €100per ton of CO_2-eq [13].

Phase III involved several developments including (*i*) the introduction of a single, EU-wide cap on emissions, replacing the previous system of national caps; (*ii*) auctioning was used as the default method for allocating allowances; (*iii*) adding more GHGs and sectors; and (*iv*) the introduction of the MSR [13].

Phase IV involved the strengthening of the program. The legislative framework for phase 4 of the EU ETS was first revised in 2018 but revised again in 2021 to reflect the more ambitious targets for its revised NDCs. The EU is seeking to reduce its net emissions by at least 55% by 2030 and become climate neutral by 2050 [13].

2) RGGI

The RGGI is applied to Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont, and Virginia. Within the RGGI states, hydrocarbon fuel-fired power plants sized 25 megawatts (MW) or larger are the regulated entities and are required to use emissions allowances to cover each ton of their carbon emissions. The RGGI states distribute the emissions allowances on the primary market at quarterly auctions. Each participating state distributes allowances in proportion to its share of the regional cap. In 2023, the minimum reserve price was US$2.50 per allowance at the auctions. The emissions allowances are tradable on the secondary market [14].

To help control the price of the emissions allowance, the RGGI regulator introduced the Cost Containment Reserve (CCR) and Emissions Containment Reserve (ECR). If the price of the emissions allowances is too high on the secondary market, the RGGI regulator issues CCR allowances as extra allowances for sale at the next auction. Conversely, if the emissions allowance price is too low on the secondary market, the RGGI regulator withholds ECR allowances from sale at the next auction [14].

This manipulation of the emissions allowances supply is necessary to maintain the stability of the emissions allowances price on the secondary market. The price mechanism is an important signal as too low prices would discourage GHG emission reduction action, while too high prices would significantly increase manufacturing businesses' costs and make them less competitive in international trade.

The RGGI also has a MRV system called the RGGI CO_2 Allowance Tracking System. This system is used by the RGGI regulator to help ensure compliance by regulated entities [14].

The aforementioned case studies of the EU and the USA reveal that a regional ETS is feasible.[6] While each Caribbean country can implement a national ETS, the better approach would be the creation of a regional ETS. This agreement is made as the Caribbean countries are too small, and a larger market is needed to ensure that there is sufficient liquidity in the market. If there is insufficient liquidity, there would be frequent price halts, settlement risk, and Herstatt's risk. Liquidity is discussed in greater detail in Section 6.

3.6. MRV system

MRV are crucial components of an ETS. The MRV system for an ETS typically involves the following steps:

1) Monitoring: Companies that are covered by the ETS are required to monitor their emissions and report them to the ETS regulator. The regulated entities should comply with the monitoring methodology that was specified by the ETS regulator.
2) Reporting: Regulated entities would be required to report their emissions data to the ETS regulator in a standardized format. Most likely the reporting will occur annually. The reporting format is designed to ensure consistency and comparability between the regulated entities and to enable the ETS regulator to calculate the overall emissions from the covered sector. The reports should include the GHG measured, the methodology for measuring the emissions, the emissions cap, and the emission reduction action pursued by the respective regulated entities.
3) Verification: The ETS regulator may verify the emissions data reported by the regulated entities by using the services of independent third-party verification auditors. The verification auditors can perform checks to verify the accuracy and completeness of the reported emissions data. The verified report can help the ETS regulator determine if regulated entities complied with their emissions caps.

3.7. Cross-border trading

The trading of emissions allowances in a regional ETS involves the participation of targeted entities from different countries, each of which has different emissions reduction targets. In a regional ETS, targeted entities in one sector in one country may purchase emissions allowances from another targeted entity in another country selling an emissions exchange. However, several issues must be addressed in this system.

Cross-border trading of emissions allowances involves the purchase of allowances by targeted entities in one country from another targeted entity in another country. The purchase of emissions allowances allows targeted entities to meet their emissions reduction targets at a lower cost by purchasing allowances from entities in other countries that have surplus emissions allocations.

However, this has significant implications for stakeholders in different countries. For instance, assume that the forestry sector is included as an NDC sector in one country, while petrochemicals are included as an NDC sector in another country. A forestry division in one country may have surplus emissions allocations as

[6]Canada has an ETS in Québec. The ETS covers several GHGs, including carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride. The ETS is applied to the following sectors transportation, heavy industry, construction, agriculture, waste, and power generation. In 2014, the ETS was linked with the ETS in Canada. Therefore, this ETS could be considered as a regional ETS [15].

forests absorb carbon from the atmosphere. The forestry division may sell its emissions allocations to a petrochemical-regulated entity from another country on the emissions exchange. This system allows for the forestry division to gain additional revenue which can be used to conserve forested areas. In comparison, the petrochemical targeted entity can choose to purchase the emissions allocations on the emissions exchange especially if this is cheaper than the cost of implementing new technologies and processes to reduce emissions, and lower than the fee for non-compliance.

A significant factor that can affect the relative price and "cheapness" of the emissions allocations in different countries is the exchange rate. Different countries in the emissions exchange may have different exchange rates. This can make the price of an emissions allocation in one country very cheap and expensive in other countries. Ultimately, the regional trading of emissions allocations can encourage the countries with the lowest exchange rates and the most carbon sinks to be the net recipient of income as they can sell their emissions allocations. Likewise, the countries with the strongest exchange rates and the highest polluting sectors are likely to be net purchasers of emissions allocations. Furthermore, a system functioning in this manner effectively forces the highest emitters to internalize the cost of their negative externality of GHG emissions by purchasing surplus emissions allocations from the carbon sinks targeted entities.

Given the differences in the size of the Caribbean countries, the availability of carbon sinks, the different exchange rates, and the inflation rates in countries, a regional exchange ETS may be the best approach to stimulate GHG emission reduction action. It would encourage GHG emission reduction action in countries with vast carbon sinks such as Guyana and Suriname. However, it would encourage stakeholders such as the petrochemical stakeholders in countries such as T&T to purchase surplus emissions allowances. So eventually, there should be net financial flows from countries like T&T to countries like Guyana and Suriname.

Cross-border trading of emissions allowances in a regional ETS requires the exchange of funds between targeted entities located in different countries. This process can introduce a range of cross-border payment issues and currency issues, which can have significant implications for the efficiency and effectiveness of the trading process.

Cross-border payments are transactions that involve the exchange of currencies between two or more countries. In the context of cross-border trading of emissions allowances, targeted entities are required to make payments in foreign currencies to purchase allowances from entities located in other countries. However, cross-border payments can be complex and time-consuming, as they require compliance with a range of regulatory and financial requirements. Some of the key cross-border payment issues that can arise in the context of a regional ETS include:

Payment timing: Cross-border payments often require multiple intermediaries and can take several days to settle. This can introduce payment timing issues, which can affect the efficiency and effectiveness of cross-border trading of emissions allowances. Delayed payments can cause problems for targeted entities that rely on a steady flow of income to manage their cash flow and operations.

Payment security: Cross-border payments are vulnerable to fraud and cybercrime. Targeted entities engaging in cross-border trading of emissions allowances must ensure that their payment systems and processes are secure and that they comply with the necessary data protection regulations.

Currency conversion costs: Currency conversion costs can be significant in the cross-border trading of emissions allowances. These costs can include transaction fees, spread, and other charges levied by banks or financial institutions for converting currencies.

Exchange rate risks: Currency fluctuations can affect the competitiveness of targeted entities engaging in cross-border trading of emissions allowances. If the value of the currency of the country where a targeted entity is located depreciates against the currency of the country where the allowance is purchased, the cost of the allowance increases for the buyer.

The international regulatory environment: The regulatory environment surrounding cross-border payments can also pose challenges. Different countries may have different regulations governing cross-border payments, and compliance with these regulations can be difficult and expensive. In addition, targeted entities may be subject to additional reporting and disclosure requirements when engaging in cross-border payments, which can add to their administrative burden. Enhanced reporting requirements for cross-border payments can result in delays and additional costs for targeted entities. Furthermore, it can result in delays in the settlement of transactions on the emissions exchange.

To address these challenges, there must be a good payment and settlement systems for cross-border transactions.

4. Current Cross-Border Payment System

An essential component of the cross-border payment system is the Society for Worldwide Interbank Financial Telecommunication (SWIFT). SWIFT was established in 1973 to standardize the electronic communication system for payments [16]. SWIFT is a global messaging network that connects more than 11,000 financial institutions in over 200 countries. Its primary role is to facilitate secure and reliable messaging between banks, enabling cross-border payments. One of the key features of SWIFT is its standardized messaging format, which ensures that all banks can communicate with each other using a common language. This format also helps to reduce errors and delays in the payment process. Banks use SWIFT to apply standardized codes for cross-border payments. A SWIFT code specifies the sender and receiver bank without error while allowing some flexibility for the details of the transaction.

The cross-border payment system can be divided into three main stages: initiation, transmission, and settlement. The initiation stage involves the sender of the payment providing the necessary information to their bank, including the recipient's details, the amount to be transferred, and the currency to be used. This information is then transmitted to the recipient's bank via SWIFT, which acts as a messaging network connecting banks worldwide.

During the transmission stage, the sender's bank sends a payment message to the recipient's bank through SWIFT. This message contains the payment details and instructions on how to credit the recipient's account. The message is encrypted and transmitted through SWIFT's network. This is done to maintain confidentiality in the transaction.

Once the payment message has been received by the recipient's bank, the settlement stage begins. Settlement refers to the actual transfer of funds from the sender's account to the recipient's account. The settlement process can take place through various methods, including correspondent banking, which involves using intermediary banks to transfer funds between the two banks.

Despite the significant benefits that SWIFT provides to the cross-border payment system, there are still several challenges that need to be addressed. One of the primary challenges is the high cost of cross-border payments, which can be due to fees charged by banks and currency exchange rates.

Another challenge is the time taken to complete cross-border payments, which can sometimes take several days to complete. This delay can be due to various factors, including differences in time zones, the need for manual processing, and delays in correspondent banking.

Finally, there is the issue of regulatory compliance, which can be a significant challenge for banks involved in cross-border payments. Banks are required to comply with a range of regulations and anti-money laundering (AML) laws, which can be complex and time-consuming.

Indeed, there is a need for a better cross-border payment system. Blockchain emerges as a potential solution as it can provide a secure, transparent, and efficient way to transfer funds across borders while eliminating the need for intermediaries. The next section reviews blockchain and how it can be used to facilitate cross-border payments. This would be essential for the function of the potential Caribbean regional emissions trading exchange.

5. Literature Review on Blockchain

A blockchain is defined as an ordered, decentralized, immutable ledger that facilitates the recording of transactions in a network. It consists of a chain of blocks, where each block contains a list of transactions, a timestamp, and a unique cryptographic hash that links it to the previous block in the chain [17].

A blockchain has two main characteristics, namely decentralization and immutability. Blockchain is decentralized, which means its records are distributed to all the parties on a network rather than being concentrated in a central ledger. The other characteristic is immutability, which means that once the transaction is recorded, the information in the transaction cannot be changed [18].

5.1. Functionality of blockchain

Blockchain is based upon five concepts: a network of nodes, tokens for transactions, a structure, a consensus mechanism, and rules.

First is the network of nodes. A blockchain network is a distributed network of nodes, where each node is a computer or a device that is connected to the network. Each node has a copy of the entire blockchain ledger and participates in verifying transactions and adding new blocks to the chain.

The second concept is the tokens for transactions. Tokens, also known as digital currencies or cryptocurrencies, are used to facilitate transactions on the blockchain network. Transactions on the blockchain involve sending tokens from one user to another, and each transaction is recorded in a block on the blockchain. Tokens are decentralized and can be traded without the need for intermediaries such as banks or financial institutions.

The third concept is structure. The blockchain structure is a decentralized database that stores transactional data in blocks that are linked to each other in chronological order, forming a chain of blocks (hence the name blockchain) [19].

The fourth concept is the consensus mechanism. Consensus mechanisms are protocols that ensure all nodes in the network agree on the state of the blockchain. This ensures that transactions are validated and blocks are added to the blockchain securely and consistently [20].

The fifth concept is the rules. Blockchain networks are governed by a set of rules and protocols that dictate how transactions are verified, added to the blockchain, and how participants interact with each other. These rules are enforced by the network and are designed to ensure the integrity and security of the blockchain. They may include rules around how new blocks are added, how rewards are distributed, and how transactions are validated. Smart contracts are also used to automate business processes and enforce rules on the blockchain network [21].

5.2. Types of blockchains

Blockchains can be classified as either public or private [22].

Public blockchains are open to anyone who wants to participate and are fully decentralized. This means that there is no central authority controlling the network, and anyone can join the blockchain without needing authorization from a central body [22]. Examples of public blockchains include Bitcoin and Ethereum.

In comparison, private blockchains are controlled by a single entity or organization. Access to the blockchain can be restricted, and each transaction can be reviewed and verified by a central authority before it is added to the blockchain. Examples of private blockchains include Ripple and Hyperledger.

Private blockchains are typically faster than public blockchains, as the number of nodes on the network is smaller and transactions can be verified more quickly [22].

Hybrid blockchains are a combination of public and private blockchains. They provide a decentralized environment for the recording and sharing of information over a private network [22].

5.3. Bitcoin: the first blockchain

Bitcoin is a digital currency that allows online payments between parties without a need for an intermediary. Bitcoin was first described by someone under the pseudonym Satoshi Nakamoto in a paper titled "A Peer-to-Peer Electronic Cash System" [20, 22, 23]. In 2009, Bitcoin was introduced as the first cryptocurrency.

Bitcoin is a digital currency that operates on a decentralized blockchain network. It was created in 2009 and has since become one of the most popular cryptocurrencies in the world. Unlike traditional fiat currencies that are issued and regulated by central banks, Bitcoin is not controlled by any central authority or government. Instead, it relies on a decentralized network of computers to validate and process transactions [24, 25].

The process of validating transactions on a blockchain is an essential aspect of its operation. To validate a transaction on the blockchain, it must first be recorded as a block in the chain. A block contains several transactions that are bundled together and recorded in a way that ensures their integrity. This process involves verifying that the sender has sufficient funds to complete the transaction and that the transaction has not already been spent.

Once a block of transactions is assembled, it is broadcast to the network for validation. Miners on the network compete to solve a complex mathematical problem, known as a proof-of-work puzzle, to validate the block.

The first miner to find a solution to the problem broadcasts it on the blockchain network to the other miners. Then the solution is verified by the other miners. Once verified, the block is added to the blockchain, and the successful miner is compensated with Bitcoins [26].

Over 1000 cryptocurrencies have been developed since Bitcoin was introduced. However, only a few cryptocurrencies can be considered direct competitors of Bitcoin.

6. Recommended Cross-Border Payments with Blockchain

Blockchain technology can be used to facilitate cross-border transactions by providing a secure, transparent, and decentralized platform for recording and verifying transactions. Blockchain allows for faster and cheaper transactions, as there is no need for intermediaries to facilitate transactions or verify them. This can significantly reduce transaction fees and processing times, making cross-border payments more affordable and efficient.

The idea of cross-border payment through a blockchain is not farfetched. Ripple, a fintech company, offers cross-border payment services through a blockchain network.

Ripple's blockchain network, referred to as RippleNet, is a decentralized platform that enables near-instant and low-cost cross-border payments between financial institutions.

The key innovation of Ripple's platform is its use of blockchain technology to enable secure, fast, and efficient cross-border payments. The Ripple network uses a consensus protocol that enables participants to validate transactions without the need for a central authority. This helps to reduce the transaction processing time and costs associated with traditional cross-border payments.

Ripple's platform also includes a digital currency, which it calls XRP, which serves as a bridge currency that can facilitate cross-currency transactions. XRP can be used to settle payments in real time and provides liquidity to financial institutions that do not have direct correspondent banking relationships. This can help to further reduce the cost and complexity of cross-border payments.

One of the key advantages of Ripple's platform is its ability to provide near-instant settlement times for cross-border payments. This is in contrast to traditional cross-border payments, which can take several days to complete and are subject to high fees and currency conversion costs. The speed and efficiency of Ripple's cross-border payment services offer a compelling alternative to traditional payment systems, with the potential to significantly reduce the time, cost, and complexity of cross-border transactions. By leveraging blockchain technology and digital assets, the accessibility and affordability of cross-border payments, particularly for stakeholders, are unable to rely on the current corresponding banking payment system.

6.1. Need for an API

As can be seen from Ripple's experience, one step to building out a blockchain cross-border payment system involves the development of an application programming interface (API)[7] interface to enable instantaneous messaging and settlements. The API functions as a set of rules that allow the software to connect with external software. In the context of cross-border payments, an API allows a bank's payment software to connect with the payment software of an external party. API works by receiving a request from a client application and then it makes a call to the external program or web server. This is followed by the API receiving the requested information from the web server and then sending the information to the client application [27].

Consider a hypothetical example with a regulated entity in T&T, and a regulated entity in Guyana, both of which are listed on a regional emissions exchange. Assume there are brokers on the regional emissions to facilitate transactions. Assume the T&T regulated entity has an account with a broker, while the Guyanese-regulated entity may have an account with another broker.

The T&T regulated entity initiates the transaction through its broker's existing trading platform, which is connected to the emissions exchange's API. The API sends a request to the Guyanese-regulated entity broker for information. This information includes the price the Guyanese is asking for the sale of its emissions allowance and the quantity available. Information on the Guyanese-regulated entity is sent through the API. The API verifies the information and sends it back to the T&T regulated entity. The T&T regulated entity agrees to the price and initiates the payment through its broker for a specific volume of emissions allowances. The T&T regulated entity's broker sends the payment to the Guyanese-regulated entity broker. The Guyanese-regulated entity receives the payment and transfers the emissions allowances to the regulated entity in T&T.

By using an API to facilitate the transaction, the regulated entities can communicate directly with each other and eliminate the need for intermediaries and messaging services, making the process faster, more efficient, and cost-effective. The use of APIs also ensures the privacy and security of the transaction data, as the information is sent directly between the transacting parties.

Furthermore, the API ensures regulatory compliance by providing a secure and standardized interface for transacting parties to communicate with their respective banks, eliminating the need for correspondent banking relationships and simplifying the process of complying with AML, counter-terrorist financing, and know-your-customer requirements.

6.2. Need for a common currency

The currency used to facilitate the trading of emission allowances on the regional emissions exchange can have a significant impact on the efficiency and effectiveness of the trading system. A common currency approach would involve using a single currency for all transactions on the regional emissions exchange. The advantage of a common currency approach is that it can simplify the trading process, reduce transaction costs, and increase liquidity by making it easier for buyers and sellers to transact with each other. Additionally, a common currency can reduce the risks associated with currency exchange fluctuations, which can affect the profitability of trades.

A different currencies approach, on the other hand, would involve allowing regulated entities to trade emission allowances in the currency of their choice. For example, a T&T-regulated entity could choose to trade in TTD, while a Guyanese-regulated entity could choose to trade in GUY. Therefore, every time a regulated entity wants to trade an emissions allowance with a regulated entity from another country a currency conversion must occur. A properly functioning API can allow for instant currency conversions while engaging in transactions. However, given that the strength and volatility of the currencies in the Caribbean vary, there is scope for fluctuation in the profitability of the trades resulting in uncertainty and inefficiency. For this reason, the better approach would be the adoption of a single currency for the transactions on the regional emissions exchange.

[7]An API is a software that offers a service collected from other pieces of software. For example, an API on a phone.

An API will hide the internal details of how a system works and will only reveal the parts that a user is required to use.

In contrast, a user interface is designed to simplify the interaction between a user and a software. For example, the software Eviews uses a graphical user interface (GUI). The GUI allows a user to run econometric models without writing code. Simple models can be run by clicking on various tabs and buttons.

Notably, on March 31st, 2021, the Eastern Caribbean Currency Union (ECCU) piloted a digital currency called DCash [28]. DCash operates on a distributed ledger technology[8] platform, and it allows individuals in the ECCU to use a mobile wallet to make online financial transactions quickly and securely. There is an opportunity to use a common digital currency such as DCash to facilitate trading on the regional emissions exchange. Additionally, to facilitate efficiency smart contracts can be used to fill orders.

Smart contracts are self-executing contracts with the terms of the agreement directly written into code. They are designed to automatically execute and enforce the terms of the agreement, including the transfer of digital assets between parties. Consider an example.

Suppose that a petrochemical-regulated entity in T&T wants to purchase emission allowances from a forestry regulated entity in Guyana on the emissions exchange. The petrochemical-regulated entity places an order (at market or limit) for a certain number of allowances at a specified price, and the forestry-regulated entity accepts the order. The terms of the trade are encoded in a smart contract, which automatically executes the trade and transfers the digital currency from the petrochemical-regulated entity to the forestry-regulated entity once the trade is settled. The smart contract ensures that the trade is executed according to the agreed terms and that the transfer of allowances and digital currency occurs simultaneously.

Smart contracts ensure settlement, which is transferring ownership of emission allowances and the DCash/digital currency between the buyer and seller of the trade. Smart contracts also eliminate the need for a third party to act as a clearinghouse for the settlement. This automation is an attractive feature especially since a regional clearinghouse may receive a lot of transactions, and manual in-person settlement can result in errors in processing and delays from the processing of insufficient information.

Notably, the role of the smart contract is different from the role of the API. Rather, the smart contract complements the API. The API allows the petrochemical-regulated entity's broker account to connect to the forestry-regulated entity's broker account. This allows for the flow of funds from one account to another without the need for intermediaries.

In other words, the API allows the connection of the broker accounts and the transfer of funds across the blockchain. The API allows the traders to see the past and current prices and ensures that a buyer can only purchase if they have sufficient funds in their account. The smart contract ensures that when the funds are exchanged, there is also an immediate exchange of the emissions allowances. The smart contract considers the price and the volume of the emissions allowances specified by the buyers and sellers to implement a trade. Therefore, the smart contract complements the API.

6.3. Liquidity and settlements

Liquidity refers to the ability of market participants to buy or sell emissions allowances at a fair market price. A lack of liquidity can lead to wide bid-ask spreads, which can result in higher transaction costs and discourage trading activity. To ensure adequate liquidity, the emissions exchange must attract a sufficient number of market participants, such as industrial emitters, financial institutions, and speculators. The exchange should also provide transparent and timely market data, such as real-time price quotes and order book depth, to facilitate informed trading decisions.

To address liquidity and settlement issues in a regional emissions exchange, the platform should consider the following:

Market participants: The exchange should attract a diverse range of market participants to ensure sufficient liquidity. For this reason, the regional emissions exchange would be more feasible than individual Caribbean countries operating their own emissions exchange.

Market data: The exchange should provide transparent and timely market data to enable informed trading decisions. This can include real-time price quotes, historical price data, and order book depth.

Trading rules: The exchange should establish clear and enforceable trading rules, such as minimum and maximum order sizes, to ensure fair trading and prevent market manipulation.

Settlement process: The exchange should use smart contracts to automate the settlement process and reduce settlement risk. The smart contracts should be designed to ensure that both parties fulfill their obligations simultaneously and that settlement occurs in a timely and secure manner.

Payment as a service: The regulated entities brokers should allow the regulated entities to establish financial accounts to trade on the exchange. However, brokers should allow regulated entities to fund their accounts from different sources. This can include bank accounts, credit cards, money transfer organizations, and online payment providers. The brokers should allow the regulated entities to withdraw funds from their accounts to the same funding sources.

6.4. Consensus mechanism

The choice of consensus mechanism for a blockchain cross-border system on the regional emissions exchange would depend on various factors such as security, scalability, decentralization, and performance requirements. In general, a consensus mechanism is a protocol that enables all nodes in a distributed system to agree on the current state of the blockchain ledger. Consensus mechanisms ensure that all nodes have a consistent and tamper-proof view of the blockchain ledger, making it suitable for cross-border transactions.

In Proof of Work (PoW), nodes compete to solve a cryptographic puzzle, and the first node to solve the puzzle is rewarded with cryptocurrency. While PoW is highly secure, it requires significant computational power, which makes it less scalable and less environmentally friendly. Therefore, PoW may not be the most suitable consensus mechanism for the regional emissions exchange, where transactions need to be settled quickly and efficiently.

Another consensus mechanism that could be used for the regional emissions exchange is the Proof of Stake (PoS). In PoS, nodes are chosen to validate transactions based on the amount of cryptocurrency they hold. This means that nodes with a higher stake in the network are more likely to be chosen to validate transactions. PoS can handle a higher volume of transactions.

A third consensus mechanism that could be used for the regional emissions exchange is the Delegated Proof of Stake (DPoS). In DPoS, nodes vote to elect a smaller group of nodes, known as delegates, to validate transactions on their behalf. This reduces the computational power required to validate transactions and allows for faster transaction times. DPoS is highly scalable and can handle a high volume of transactions. DPoS is appropriate as a consensus mechanism for the ETS.

A fourth consensus mechanism that could be used for the regional emissions exchange is the Practical Byzantine Fault

[8]DLT is the name that is used to describe the technology of the blockchain network. It is a protocol that creates a secure, immutable, and decentralized network that allows for the storage of information. As it is decentralized, the information is shared across all parties in the network. When the DLT is applied, once the information is stored, it becomes an immutable (unchangeable) database and is governed by the rules of the network.

Tolerance (PBFT). In PBFT, nodes are organized into a group of validators, and each validator validates transactions independently. PBFT is highly secure and can handle a high volume of transactions. PBFT is also appropriate as a consensus mechanism for the ETS.

6.5. Security and cyber defense

Security is a crucial aspect of the blockchain-based cross-border payment system on the regional emissions exchange. Since these systems are based on distributed ledgers that store financial information, they may be targeted by cyber attackers seeking to exploit vulnerabilities and steal funds.

One of the primary security concerns in a blockchain-based cross-border payment system is the risk of unauthorized access to the network. Cybercriminals may attempt to gain unauthorized access to the blockchain network and manipulate transactions or steal assets. They may also attempt to launch a distributed denial of service attack on the network, which can slow down or even crash the system.

To prevent unauthorized access, blockchain cross-border payment systems on the regional emissions exchange typically use multiple layers of security. These may include multi-factor authentication, secure access protocols, encryption, and firewalls. Additionally, the use of private and permissioned blockchain networks can limit access to only authorized parties. Furthermore, smart contract audits can be performed to ensure that they are free of vulnerabilities and security loopholes. Regular security testing can also be performed to identify any weaknesses in the system.

6.6. Reliability and Herstatt's risk

Herstatt's risk refers to the risk of a transaction to fail after one party has initiated the transaction. This is a real risk. In 1974, Bankhaus Herstatt failed to settle a transaction after receiving a payment. This caused a chain reaction of defaults which cost US$620 million to the global banking sector [29]. To address Herstatt's risk, several measures can be taken:

Pre-funding: Pre-funding involves requiring both parties to deposit funds into a designated account before the transaction can take place. This ensures that both parties have fulfilled their obligations before the transaction is completed.

Smart contracts: Smart contracts can be programmed to automatically execute payment only when certain conditions are met.

7. Conclusion

The CARICOM Member States have submitted their NDCs to the UNFCCC for the Paris Agreement. However, the implementation of their NDCs has been hindered by the lack of financial support from the international community. Fortunately, the Paris Agreement includes market-based mechanisms to incentivize GHG-emitting stakeholders in countries to reduce their emissions, including an ETS. This system allows for the trading of emission allowances between stakeholders to facilitate compliance with emissions targets. Adopting an ETS can help CARICOM Member States implement their NDCs and reduce GHG emissions.

However, implementing an ETS in the Caribbean region requires a cross-border payment system to facilitate the sale and transfer of emission allowances across participating countries. Unfortunately, the Caribbean's cross-border payment system presently relies on correspondent banking relationships, which is slow, inefficient, and vulnerable to derisking.

Blockchain technology emerges as a possible solution for a cross-border payment system as it eliminates the need for intermediaries, such as correspondent banks, to facilitate cross-border transactions. Thus, a blockchain cross-border payment system can be faster, cheaper, and more secure than the traditional correspondent banking cross-border payment system.

This study advocated in support of the development of a blockchain cross-border payment for a potential regional ETS in the Caribbean. The regional ETS should be an exchange, which allows for the trading of emission allowances on the secondary market.

A regional ETS is a better option rather individual countries adopting national ETS. This argument is made because the Caribbean is comprised of small islands with small markets, and thus the region is needed to form a larger market to ensure that there is sufficient liquidity.

Several issues must be considered to develop a functional blockchain cross-border system for a regional emissions exchange.

Firstly, the development of an API is crucial to allow different systems to interact with each other seamlessly. The API will enable the exchange of data between the blockchain network and other systems, such as trading platforms and financial institutions. This will ensure that the necessary information is available to all parties involved, allowing for efficient and effective transactions.

Secondly, the use of a common digital currency is essential to enable seamless cross-border transactions. A digital currency like DCash can be used to achieve this.

Thirdly, smart contracts can be used to automate the market and limit orders. Smart contracts can ensure settlement as they ensure that the correct volume of emissions allowances is transferred to respective regulated entities at agreed-upon prices during transactions. Smart contracts are also required to mitigate Herstatt's risk.

Fourthly, a large volume of traders is required to ensure the liquidity of the emissions exchange. For this reason, a Caribbean regional emissions exchange is more feasible than the development of individual emissions exchanges in different countries.

Fifthly, selecting an appropriate consensus mechanism is crucial to ensure that all transactions are validated and recorded accurately. The consensus mechanism is the process by which nodes in the network agree on the state of the ledger. The consensus mechanism must be able to handle high transaction volumes, provide a high degree of security, and be energy efficient.

Sixthly, security is of utmost importance in a blockchain cross-border system. Several measures can be taken to ensure the security of the system, including encryption, multi-factor authentication, and the use of secure communication protocols.

Notably, the recommendation for an ETS can be implemented by any region seeking to implement their NDCs. Important issues to be considered in the design of the ETS include the emissions cap, GHGs included, sectors covered, distribution of the emissions allowances, trading of emissions allowances, demand, supply, and price of emission allowances, and penalties for non-compliance. However, blockchain can be integrated into the payment system to allow efficiency in cross-border payments and ensure quick settlement of transactions.

Indeed, a blockchain cross-border payment emissions exchange can be an excellent tool to stimulate climate action and help a region achieve its NDCs. It effectively incentivizes emitters to seek the most cost-efficient way to reduce the emissions of a region. This is good because it facilitates the adoption of low-carbon technologies and practices. Moreover, it can help a region work toward the overall goal of limiting global temperature rise to well below 2° C above pre-industrial levels by the end of this century.

Ethical Statement

This study does not contain any studies with human or animal subjects performed by the author.

Conflicts of Interest

The author declares that he has no conflicts of interest to this work.

Data Availability Statement

The United Nations Framework Convention on Climate Change datathat support the findings of this study are openly available at https://www4.unfccc.int/sites/submissions/indc/Submission%20Pages/submissions.aspx.

Author Contribution Statement

Don Charles: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration.

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How to Cite: Charles, D. (2023). A Blockchain Cross-Border Payment System to Enable a Potential Caribbean Regional Emissions Trading Scheme. *Green and Low-Carbon Economy*. https://doi.org/10.47852/bonviewGLCE3202825