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Tracking the Carbon Trail

Harmonizing Sustainability and Finance: EcoChain-Link

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The escalating climate crisis underscores the pivotal need to curb carbon emissions. Carbon and methane account for nearly 90% of greenhouse gases (GHGs). If fossil fuel emissions could be carefully controlled from their sources to consumption, the market would reinforce incentives for companies to reduce their emissions. The change is emphasized when EcoChain-Link connects the carbon footprint in the green bond markets.

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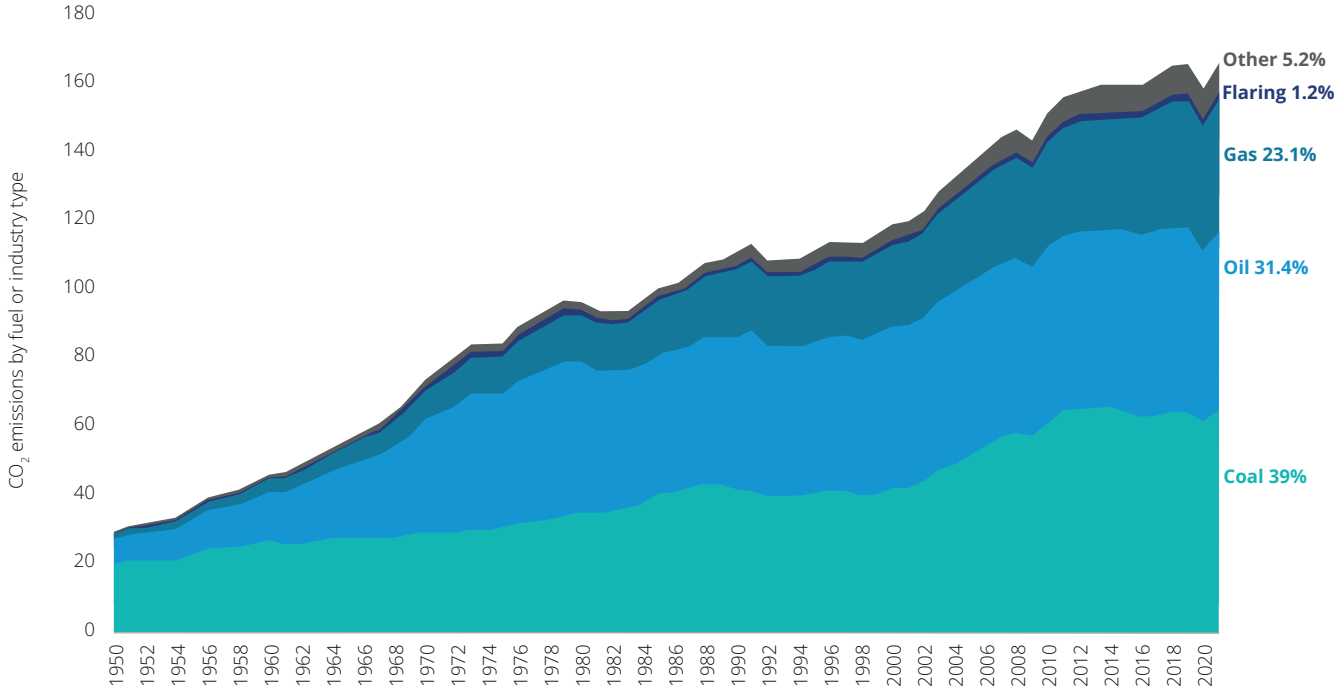
Executive Summary

Climate change poses an urgent threat requiring concerted global action to curb carbon emissions. Fossil fuels account for over two-thirds of greenhouse gas emissions, highlighting the need for transparent emissions tracking across the value chain. Meanwhile, financing of sustainable initiatives remains crucial as investments accelerate worldwide.

Fossil fuels CO_2 emissions, a growing concern reaching ~157 billion CO_2 tones in 2021



Source: https://ourworldindata.org/grapher/CO_2-by-source

We propose an integrated blockchain solution addressing limitations in existing carbon accounting frameworks as well as accessibility barriers inhibiting sustainable capital flows. The proposed model incorporates a standardized emissions ledger alongside a digital sustainable finance platform to demonstrate end-to-end functionality spanning carbon tracking, sustainable asset origination, and trading.

By streamlining taxonomies, disclosures, and settlement processes through these shared systems, the approach aims to drive impact measurability, investment flow prioritization, and mitigation incentive alignment according to consensus environmental standards. Initial prototype deployment will validate technical capabilities within discrete fossil fuel supply chains with broader participation required over the long run.

Linking carbon markets to the finance platform promises to reinforce integrity while expanding emissions pricing signals. Education-driven inclusion and risk examinations also look to deepen sustainable market participation. Overall, a collaborative governance model leveraging distributed ledger and smart contract technologies presents a robust pathway toward the transparency, efficiency, and scalability needed in responding to shared climate challenges and opportunities.

The system will develop an immutable ledger leveraging Internet of Things (IoT) sensors for transparent tracking of emissions across the value chain. By recording carbon footprints from extraction to combustion on blockchain's tamper-proof distributed ledger, accountability and transparency will be strengthened.

The ledger will be populated with authenticated emissions data from sensors and metrology tools, providing a single source of truth. Smart contracts will grant private access to participants facilitating trust and collaboration across entities. This is done through industry average carbon coefficients by fuel embedded in a smart contract.

The emissions ledger will integrate with a tokenized sustainable capital markets platform where sustainability-linked instruments can be issued, traded, and settled. The system will automate deal processing for sustainable bonds and other assets using configurable smart contract templates tailored to instrument characteristics and regulatory requirements. Mainstreaming will be enabled by interfacing with traditional and digital payment rails. Stablecoins and Central Bank Digital Currencies (CBDCs) are envisioned to support fully digital settlement.

A key innovation is utilizing the emissions data from the tracking ledger to directly incentivize mitigation through sustainable finance. Smart contracts will automate carbon credit issuance once emissions reductions from offset projects are verified on the blockchain.

Additional benefits include simplifying sustainable investments by reducing participation barriers and educating stakeholders. Standardizing sustainable bond frameworks and disclosures in the secondary market will strengthen mainstream adoption. The solution ultimately aims to combat greenwashing by mandating transparency and honest communication of sustainability performance.

Expected outcomes encompass comprehensive emissions traceability, exponential growth in innovative sustainable capital instruments, restored credibility for carbon markets, and enhanced ambition for climate change mitigation.

The synergistic fusion of accurate emissions tracking and tokenized sustainable finance can accelerate the urgent transition to a low-carbon economy. EcoChain-Link details the objectives, scope, framework, components and implications of the proposed solution. We invite stakeholders across industries, governments and civil society to collaborate on this blockchain-based sustainability platform for our collective future.

Carbon dioxide emissions coefficients by fuel

Carbon dioxide (CO_2) factors:	Kilograms CO_2 Per unit of volume or mass		Kilograms CO_2 Per million Btu
For homes and businesses			
Propane	5.75	gallon	62.88
Diesel and home heating fuel (distillate fuel oil)	10.19	gallon	74.14
Kerosene	9.88	gallon	73.19
Coal (all types)	1,764.83	short ton	95.92
Natural gas	54.87	thousand cubic feet	52.91
Finished motor gasoline	8.10	gallon	67.39
Motor gasoline	8.78	gallon	70.66
Residual heating fuel (businesses only)	11.24	gallon	75.09
Other transportation fuels			
Jet fuel	9.75	gallon	72.23
Aviation gasoline	8.31	gallon	69.15
Industrial fuels and others not listed above			
Petroleum coke	14.92	gallon	102.12
Nonfuel uses			
Asphalt and road oil	11.91	gallon	75.35
Lubricants	10.70	gallon	74.07
Naphthas for petrochemical feedstock use	8.50	gallon	68.02
Other oils for petrochemical feedstock use	10.26	gallon	73.96
Special naphthas (solvents)	9.04	gallon	72.38
Waxes	9.57	gallon	72.60
Coals by type			
Anthracite	2,601.67	short ton	103.69
Bituminous	2,169.77	short ton	93.24
Subbituminous	1,698.80	short ton	97.13
Lignite	1,274.52	short ton	98.27
Coke	3,258.37	short ton	113.67

Source: Carbon factors provided by the U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, Tables A19, A-24, A-31, and A-215. Heat content of fuels provided by the U.S. Environmental Protection Agency Greenhouse Gas Emissions Factor Hub, survey Form EIA-923, and Appendix Tables A1-A3 of the EIA Monthly Energy Review

Introduction

Embracing emission reduction efficiency in capital markets

The global community faces escalating concerns of climate change and the pressing need to curtail carbon emissions has reached critical levels. As confirmed by the Intergovernmental Panel on Climate Change (IPCC), our planet's average temperature has surged by an alarming 1.2 degrees Celsius above pre-industrial levels. The World Meteorological Organization (WMO) reinforces this urgency by reporting a record high concentration of carbon dioxide (CO_2) in the atmosphere, which stood at 414.0 parts per million in 2020. These elevations are primarily attributed to human activities, particularly the combustion of fossil fuels.

Fossil fuels encompassing coal, oil, and natural gas, emerge as key contributors to this disconcerting trend. The Global Carbon Atlas underscores their dominant role indicating that nearly 70% of global greenhouse gas emissions emanate from the combustion of fossil fuels with CO_2 as the primary culprit. These emissions stem from diverse sectors including energy production, transportation, industry, and residential consumption. It is pivotal to acknowledge the central role played by the fossil fuel industry in this narrative.

A growing consensus underscores the urgency of deploying innovative financing solutions to underpin green initiatives and sustainable projects. Mitigating climate change has intensified focus on transitioning towards renewable energy sources, enhancing energy efficiency, and fostering the adoption of sustainable practices across a spectrum of industries. Bloomberg reported that the issuance of impact bonds (i.e., green, social, sustainability and sustainability-linked) totalled $939 billion in 2023, up 3% on the same period last year.

These financial instruments are integral in channeling resources towards environmentally beneficial projects. In response to the intertwined challenges posed by the imperative of tracking and mitigating carbon emissions linked to fossil fuels and the burgeoning demand for innovative green financing, we propose the development of a blockchain-based carbon tracking mechanism seamlessly integrated with a sustainable capital market platform. This holistic solution endeavors to usher in a new era characterized by transparency, efficiency, and inclusivity in the global battle against climate change while promoting sustainable finance on a universal scale.

Problem Statement

Existing carbon accounting lacks comprehensive traceability across industries and organizations, impeding transparency in emissions data. Ensuring reliability and traceability of emissions data remains challenging due to inconsistent standards and data quality. Environmental, Social, and Governance (ESG) taxonomies categorize sustainable investments but lack applicability standards across markets, hindering funding for genuine eligible activities or projects. Streamlining taxonomies based on consensus standards can channel capital to verified high-impact projects. Many climate solutions struggle to secure funding due to awareness, regulatory, or risk issues. Reducing participation barriers and educating stakeholders can democratize sustainable finance. "Greenwashing" obstructs sustainable capital channels, necessitating disclosure standards and honest communication to restore market credibility. Strengthening green bond frameworks and standardizing structures, disclosure, and secondary market support can enhance sustainability. Developing mechanisms for credit issuance and trading can promote both mitigation and investments. We will further discuss in detail the major problems addressed earlier:

Traceability and transparency of carbon emissions data across sectors

Existing carbon accounting lacks comprehensive traceability across industries and organizations. Mechanisms struggle to provide a complete picture of emissions associated with economic activities. Ensuring reliability and traceability of emissions data remains challenging due to inconsistent reporting standards and data quality issues. A standardized framework is needed to accurately track emission flows throughout interconnected value chains.

Streamlining ESG taxonomies to unlock sustainable capital

ESG taxonomies categorize sustainable investments, but applicability across capital markets can be complex. Variations in defining and classifying sustainable activities may hinder directing funds to genuine solutions. Harmonizing taxonomic frameworks, based on consensus standards, supports channeling capital toward verified high-impact projects.

Expanding access to sustainable opportunities

Many valuable climate solutions struggle to obtain sufficient funding due to limited market awareness, regulatory barriers, or risk perceptions. Reducing participation minimums can broaden the investor base and democracy of sustainable finance. Coordinated efforts are also needed to educate stakeholders and evaluate innovations de-risking sustainable returns.

Developing robust green bond markets

To compete with conventional bonds, green bond frameworks require strengthening. Investors currently face unfamiliarity and liquidity concerns. Standardizing issue structures, disclosure, and secondary market support would professionalize the asset class and deepen pools of sustainable capital.

Integrating carbon markets with green finance

Attaching verifiable carbon credits to labeled instruments directly incentivizes mitigation. Yet carbon markets see limited linkage to sustainable capital raising. Developing mechanisms for credit issuance and trading coordinated with financing programs could mutually enhance mitigation ambition and investment opportunities.

Combating greenwashing with transparency

As consumers increasingly prioritize environmental and social considerations, some employ misleading branding without substance. This "greenwashing" obstructs channels for directing capital to bona fide solutions. Mandating disclosure standards aligned with global compacts and honest communication is critical to distinguish leaders and restore credible market signals supporting a just transition.

The proposed solution will develop reusable smart contract frameworks and deploy a permissioned blockchain network to demonstrate functionality of the emissions tracking and green finance platform linking both Ecochain 1 and EcoChain 2 together.

Objective and Scope

The proposed solution will develop reusable smart contract frameworks and deploy a permissioned blockchain network to demonstrate functionality of the emissions tracking and green finance platform linking both Ecochain 1 and 2 together.

EcoChain 1: Greenhouse Gas Emissions Tracking Using Blockchain:

Fossil fuel combustion accounts for over 90% of carbon dioxide emissions globally. Additionally, methane leaks from oil and gas extraction contribute significantly to climate change. There is a need for improved tracking and verification of emissions from these sectors.

Objective functionality:

- Develop a blockchain-based system to provide transparent, immutable reporting of greenhouse gas emissions across the fossil fuel value chain from extraction to combustion.
- Leverage Internet of Things (IoT) sensors and other real-time data sources to digitally track carbon footprint with a high degree of reliability.

EcoChain 2: Sustainable Capital Markets Platform

There is untapped potential to scale up sustainable investments through innovative sustainable financial products and markets.

Objective functionality:

- Build a blockchain platform for issuance, trading, and settlement of tokenized sustainable assets.
- Design smart contract templates for use with sustainable bonds and other instruments to streamline deal processing while ensuring regulatory compliance.
- Integration of the platform with traditional and digital payment systems to facilitate mainstream adoption.
- Explore stablecoin and Central Bank Digital Currency (CBDC) integration to lay foundations for fully digital, globalized sustainable capital markets.
- Integrate the emissions ledger with smart contracts to automate the issuance of carbon credits traceable to reductions achieved through carbon offset projects.

Existing carbon accounting lacks comprehensive traceability across industries and organizations. Mechanisms struggle to provide a complete picture of emissions associated with different economic activities. Ensuring reliability and traceability of emissions data remains challenging due to inconsistent reporting standards and data quality issues. A standardized framework is needed for accurately tracking emissions flows throughout interconnected value chains.

Solution

Tackling the core obstacles of carbon emissions tracking stands as a significant stride towards nurturing sustainability and instilling accountability.

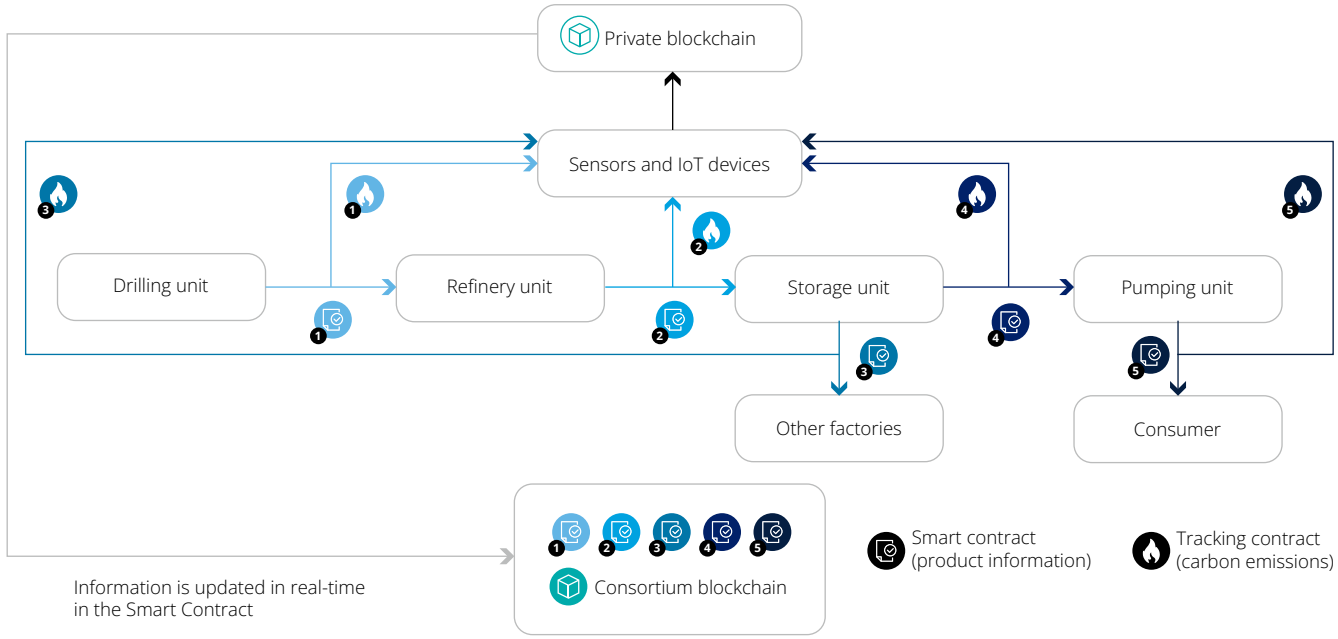


Figure 1: Utilizing smart contracts and private/consortium blockchains

EcoChain 1: Greenhouse Gas Emissions Tracking Using Blockchain

Purpose

There is a pressing demand for comprehensive and secure systems that can track and trace carbon emissions throughout the entire lifecycle of energy resources ranging from their initial production stages to the final distribution to end-users. We provide an integrated approach aimed at establishing a robust and secure system for tracking and tracing carbon emissions across the entire lifecycle of energy resources spanning from production to distribution. The utilization of private blockchain technology, IoT devices, and smart contracts, significantly improves transparency, guarantees data integrity and streamlines response mechanisms.

Approach

The proposed approach for improving carbon emissions tracking is based on integrated private blockchains and IoT devices in the fossil fuel supply chain using smart contracts to track emissions. Each step plays a critical role in enhancing traceability and security within the carbon emissions monitoring process. Within this approach, two types of blockchains are employed: private and consortium, which restrict access to trusted entities, ensuring end-to-end visibility.

Our approach as a step-based process utilizing smart contracts and private/consortium blockchains (as shown in Figure 1) is as follows:

1. The **drilling unit** initiates a smart contract with the refinery unit specifying product information, quantity, and conditions. Upon approval, shipping starts, and the drilling unit initiates a tracking smart contract to monitor carbon emissions using IoT devices. Both units can check the tracking contract for shipping violations.
2. The **refinery unit** initiates a smart contract with the storage unit specifying product information.
3. The **storage unit** initiates smart contracts with other factories and the pumping unit, specifying product information. Tracking contracts are also initiated to monitor emissions.
4. The **pumping unit** initiates a product information smart contract with the consumer. The consumer can check previous contracts for quality and emissions violations via the consortium blockchain.
5. In addition, **smart contracts with the consumer** will connect the private blockchain with the consortium blockchain to update the carbon count and to feed financial instruments linked to carbon reduction targets. Interoperability is achieved through Application Programming Interface (API) gateway connection as data conductor with standardized queries.

Product and carbon footprint information smart contracts are only accessible to permissioned participants on the private blockchain while tracking contracts are visible to all participants on the consortium blockchain.

In summary, this process utilizes two primary smart contract types:
· Product information contracts specifying product details and quantities including underlying carbon credit and conditions between parties, with restricted access on the private blockchain.
· Tracking contracts monitor carbon emissions and quality violations using IoT devices. These are visible to all parties on the consortium blockchain.

The step-based approach allows each entity in the supply chain to initiate appropriate contracts while maintaining privacy and enabling collective transparency around emissions tracking.

Underlying Technologies

Layer	Private	Consortium	Justification
User Interface (UI)	Hyperledger Composer	Not applicable	· Refer to justification provided in section EcoChain 2, underlying technologies
IoT	Leveraging on existing infrastructure	Not applicable	· E.g., Well test and production logging tools flow measurement systems, tank gauging systems, etc.
Smart contract	Daml	Daml	· Daml is designed with strong privacy and data isolation in mind. It enables the creation of confidential contracts that ensure sensitive data remains private between the involved parties. · Daml is blockchain-agnostic; it provides flexibility and future-proofing for blockchain applications. · It has a developer-friendly environment and syntax. · It is well-suited for implementing complex applications with multiple participants, intricate business logic, and conditional workflows. · It aims to prevent common smart contract bugs and vulnerabilities, such as reentrancy attacks and integer overflows. · Daml includes advanced contract templates that allow developers to define complex agreements, and workflows with ease.
Interoperability protocols	Digital asset interoperability protocols		· Alternatives can be pursued, such as Weaver, Firefly, and YUI.
Distributed Ledger Technologies (DLT) network	Hyperledger Fabric	Hyperledger Besu	· Refer to justification provided in section Ecochain 2, underlying technologies for Hyperledger Fabric and Besu.

Key Considerations

There are critical considerations in the integration of blockchain technology, smart contracts, and IoT devices for emissions tracking. These elements combine to create a robust, transparent, and secure system for tracking emissions throughout the lifecycle of energy resources. The key considerations discussed are designed to leverage the inherent security of private blockchains, enhance traceability through IoT devices, and provide real-time notifications.

Smart contracts housed within private blockchains ensure restricted access and inherent security. They serve as the backbone of emissions tracking by seamlessly integrating with IoT devices, automating tasks based on data triggers, and executing predefined actions in real-time.

Private blockchains are utilized to store emissions data collected by IoT sensors. They grant participants control over data visibility providing a secure and confidential platform for emissions tracking. The blockchain's inherent security, bolstered by cryptographic techniques and hashes, ensures data integrity and confidentiality.

IoT devices play a pivotal role in emissions tracking by collecting real-time data. They enhance traceability using sensors and identifiers, creating a wireless monitoring network for continuous data capture.

- IoT devices enable end-to-end **traceability** of emissions ensuring that data is captured at every stage of the energy resource lifecycle. Blockchain technology provides tamper-proof storage of smart contracts and emissions data safeguarding against unauthorized alterations. The **security** measures inherent in the blockchain eliminate the need for additional encryption techniques.

- **Microcontrollers** coordinate the activities of IoT devices ensuring efficient and synchronized data collection. Smart contracts trigger instant **notifications** in the event of violations allowing for swift responses to breaches.

In summary, this solution harnesses the synergies between blockchain, smart contracts, and IoT devices to create a trusted and transparent emissions tracking system. Key considerations revolve around leveraging the security and automation capabilities of blockchain technology, offering participants control over data visibility through private networks, and providing timely notifications for compliance monitoring. This integrated approach addresses the challenges of emissions tracking while contributing to a sustainable and accountable energy ecosystem.

Feasibility

To achieve a real-world carbon tracking solution, data would need to flow in a multi-layer fashion across the network. Industries deploying existing IoTs, with standardized metrics and technical disclosure capabilities will be better positioned for change:

Existing supply chain and IoT structure

The concentrated nature of fossil fuel production facilitates emissions monitoring. A limited set of major players dominate extraction and refining ensuring accessibility to operational data reported under regulatory guidelines. This concentration streamlines data collection and validation processes makes the comprehensive tracking reasonably practical to implement.

Defined productivity metrics

Well-established productivity ratios within coal, oil, and gas operations provide clear benchmarks for assessing lifecycle carbon outputs. Incorporating these ratios into smart contracts simplifies the processes of monitoring and verification. Pre-defined operating parameters enhance accuracy and transparency of emissions calculations.

Leveraging technical capabilities

Blockchain's inherent immutability bolsters reported data reliability while integration with IoT sensors improves real-time monitoring and independent validation. Publicly available financial disclosures offer an additional data point for ensuring integrity. These technical capabilities uphold principles of transparency when combined with supply chain assessment data.

Potential Benefits of Multi-Stakeholder Collaboration

Supply chain optimization for producers

Fossil fuel companies can leverage the private blockchain network to strengthen supply chain visibility and accountability. Immutable records of data facilitate contractual agreements and performance tracking across multi-party operations. Over time, benchmarking on the platform may highlight optimization opportunities.

Regulatory and policy making

Granting regulatory authorities access provides oversight of carbon reporting. Near real-time emissions data empowers fact-based policy decisions and infrastructure planning aligned with decarbonization goals. The capacity for scenario modeling supports impact forecasting of mitigation strategies.

Market transparency for investors

Tokenization of carbon credits coupled with emissions disclosures delivers transparency of production sustainability metrics. This equips investors to discern investment risks and opportunities relating to climate policy. Standardized credibility of offsets also supports the role of capital in incentivizing emission reduction projects.

Scope Boundaries

The scope is tightly focused on carbon emissions tracing specifically for fossil fuels. The priority is developing a comprehensive tracing system for this sector rather than expanding to others. While integration with sensors and financial systems occurs, the scope does not include building new hardware or extensive integration with external financial reporting systems. Boundaries are delineated to maintain focus on the core fossil fuel emissions tracing capabilities such as:

Carbon tracing for fossil fuels

The primary scope revolves around carbon tracing exclusively within the fossil fuel sector. It entails the creation of a comprehensive carbon tracking system dedicated to monitoring and tracking emissions associated with the use of coal, oil, and natural gas. The project will not expand its focus to include other sectors or emission sources beyond fossil fuels. However, it acknowledges that certain non-fossil fuel dependent sectors with high carbon emissions, such as cement manufacturing and select land-use cases, may share similar principles and methodologies that can be explored separately.

Integration with sensors and IoT

While the project incorporates sensor technology and IoT devices for data collection and monitoring, it will rely exclusively on existing and compatible sensor systems for data input. The project does not include the development or creation of new sensor hardware. This limitation ensures that the project's resources remain dedicated to its core objectives.

Integration with financial and tax systems

The integration with financial statement and direct and indirect tax reporting systems is an essential component within the project's context. However, this integration will be limited to the extent necessary to validate data accuracy and reliability. The project will not engage in extensive integration with external financial reporting systems or develop new financial or tax-related software tools.

EcoChain 2: Sustainable Capital Markets Platform

Purpose

In order to authenticate transactions, guarantee finality, and provide the relevant information to the correct party, such as the correct rights and obligations defined for each party, the current infrastructure and market practices demand complete trust in the central operator. In contrast to the current infrastructure, the tokenization of sustainable bonds is used to build a network of domains that can communicate with one another. This enables the development of interconnected, yet distinct, permission-based domains to avoid having a single operator in charge of the complete end-to-end workflow and to host all participants. Further, the following features are benefits of the tokenization:

- Direct access for retail investors: These investors can invest low amounts. As a result, more retail investors are financing green initiatives, increasing market demand for items that can be proven to be green investments will require lowering costs.
- Traditional and on-ledger stable coin payments: Workflows that enable both stablecoins and conventional payment methods have been built.
- Monitoring the real-time environmental impact of capital market products: Industry participants have significant potential to drive global change in the technologies defining green claim trust and credibility because of the inherent capabilities of blockchain.

Genesis, a prototype created by BIS Innovation Hub and the Hong Kong Monetary Authority, uses numerous technologies and offers access to retail investors directly in contrast to existing digital bond Proofs of Concept (POCs). It also exemplifies how DLT and smart contracts may synchronize and improve the efficiency of such a convoluted multi-party workflow.

With a unified view of the whole trade lifecycle and a single source of truth that automates market rules and complies to market regulations, the prototype fosters market efficiency. As seen below, the capacity to carry out numerous tasks simultaneously improves operational effectiveness and reduces errors and disagreements.

Approach

The approach leverages technology including DLT to enhance transparency and efficiency across the entire issuance lifecycle. The following steps provide an overview of this approach:

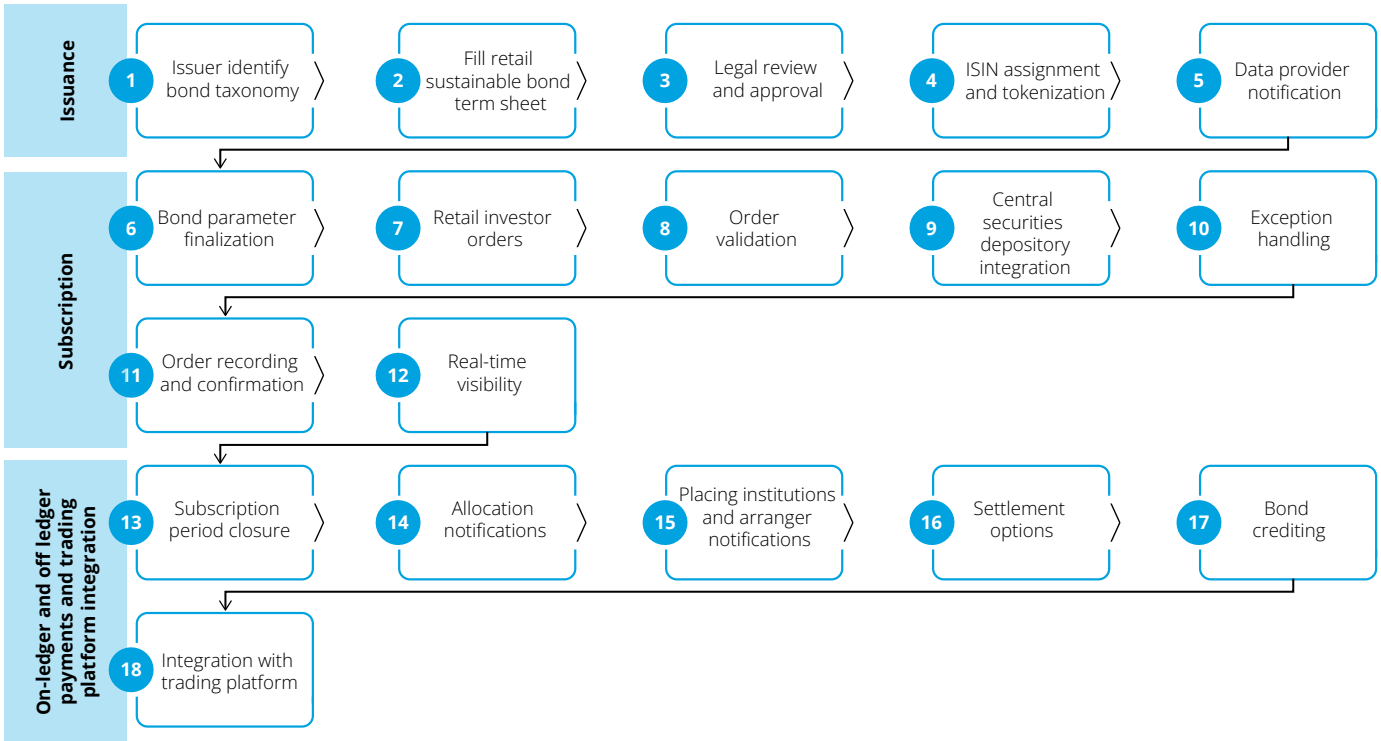


Figure 2: Retail green bond issuance and lifecycle workflow design

Detailed guide - Figure 2: Retail sustainable bond issuance and lifecycle workflow design

1. The issuer leverages direct access to certified ESG taxonomies. An efficient interface facilitates the transformation of proprietary data into ESG bond taxonomy-aligned data.

2. The issuer completes a digital and simplified retail sustainable bond term sheet. Arranger(s) are selected during this phase.

3. Once the term sheet is finalized by the issuer, legal counsel and arrangers are immediately notified in real-time. Legal review and approval take place on a platform operating across the DLT network.

4. An International Securities Identification Number (ISIN) is assigned to the retail sustainable bond. Tokenization of the bond for issuance to retail investors is facilitated through a utility.

5. Data providers are notified in real-time about newly issued bonds. This notification allows for the preparation of a data stream for ongoing reporting and project verification.

6. The issuer finalizes bond parameters in collaboration with arrangers. The subscription phase is initiated with real-time notifications to all entitled parties.

7. Retail investors review the bond term sheet and submit their orders through placing institutions. They select their preferred payment method, including traditional fiat or tokenized cash (if regulatory requirements permit).

8. Placing institutions validate retail investor's applications. Real-time checks ensure the validity of retail investors and prevent duplicate orders.

9. Orders are automatically transmitted to the Central Securities Depository (CSD). Smart contracts verify retail investors' fund availability.

10. Any exceptions are promptly communicated in real-time to relevant stakeholders.

11. Valid orders are automatically recorded on the ledger. Retail investors receive real-time confirmations. Cash balances are locked, and digital assets and green efforts become visible.

12. Issuers, CSDs, and arrangers have real-time visibility into the quantity-based issuance on subscriber lists and order books.

13. The subscription period is automatically closed on the specified date. Smart contracts run allocation logic to determine final allocations for each investor.

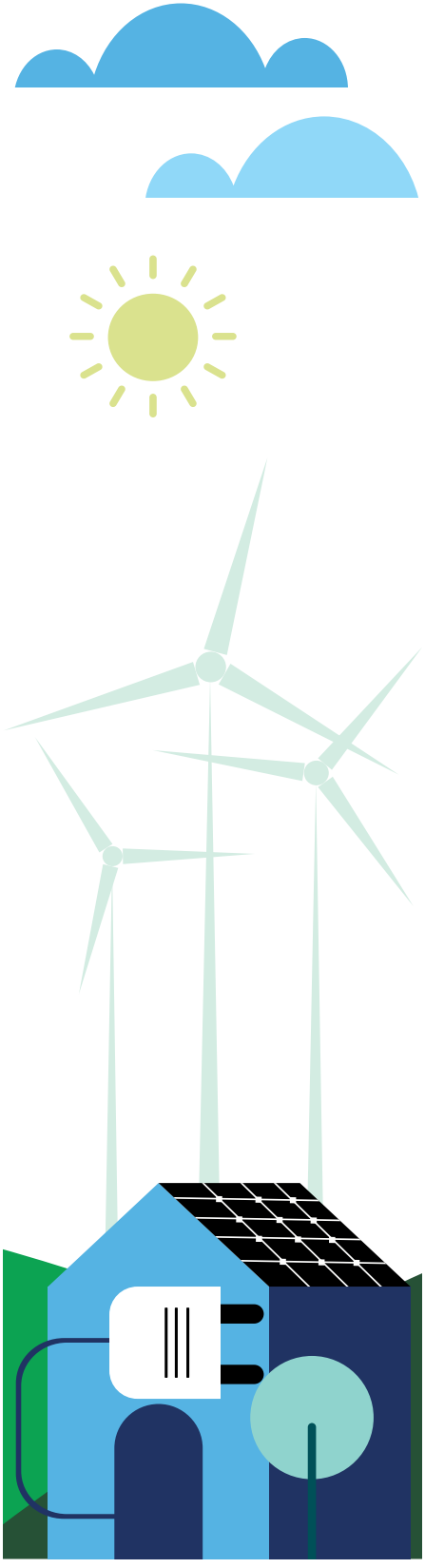
14. Investors receive real-time notifications of their final allocations and interest earned on locked cash (if applicable).

15. Placing institutions and arrangers receive real-time allocation results for their clients and placing banks.

16. On the issuance date, settlement occurs either through fiat or on-chain tokenized cash (e.g., stablecoin or CBDC), depending on the chosen method.

17. Retail bonds are credited to placing institutions' accounts at the CSD. Retail investors have real-time visibility of cash debits, interest paid on locked cash, and bond credits.

18. The approach integrates seamlessly with trading platforms to enable secondary market trading.



Underlying Technologies

Layer	Technology	Justification
Bond issuance and depository network	Hyperledger Fabric	· Modular and extensible architecture allowing complex financial instruments and adapt to evolving regulatory requirements. · Hyperledger fabric's permissioned network model allows for precise control over access rights and permissions. This ensures that only authorized entities can participate in the network enhancing security and compliance. · Robust privacy features include private channels and private data collections. These features enable secure and confidential transactions between specific participants while still maintaining transparency for regulators and auditors. · Scalable architecture, with support for multiple consensus mechanisms, ensures that the network can handle high transaction throughput without compromising performance. · Membership Service Provider (MSP) framework that manages user identities and roles within the network. · Depending on the specific use-case, participants have the flexibility to choose the most suitable consensus algorithm. · Designed to integrate with existing systems and databases seamlessly.
Secondary market trading	Hyperledger Besu	· Fully compatible with Ethereum standards and APIs. This compatibility allows for seamless integration with existing Ethereum-based applications, smart contracts, and decentralized applications (DApps). · Processes transactions by maintaining a data storage of networks (blocks). This architecture ensures data consistency and synchronization across the network, and it is critical for maintaining a single source of truth in secondary market trading. Participants can access and validate transaction history, ownership records, and asset provenance. · Provides client API interfaces that enable developers to interact with the blockchain network. · Many assets in the secondary market are tokenized, including digital securities, tokens representing ownership in real assets, and cryptocurrencies. Hyperledger Besu's support for token standards, such as ERC-20 and ERC-721, ensures that a wide range of tokenized assets can be traded within the network. · Offers privacy features including private transactions and private contracts · Architecture and consensus mechanisms ensure scalability and performance · Interoperability with other blockchain networks and protocols allows for the seamless movement of assets between different markets and ecosystems
Smart contract	Daml	· Strong privacy, portable across blockchains and easy development flow and simplifies implementation of complex apps
Interoperability	Digital asset interoperability protocols	· Alternatives can be explored: ConsenSys Weaver, Firefly, and YUI
UI	Hyperledger composer	· Provides a high-level domain-specific language for defining blockchain network models · Offers a user-friendly modeling language that abstracts complex blockchain concepts · Allows for the definition of access control rules and permissions within the modeling language · Promotes modularity and reusability in blockchain network models · Access to a supportive community to significantly expedite UI development and troubleshooting
Payment settlement	RTGS (Fast payment system) Unified payment interface, microtransactions, CBDC, and stablecoins	
Other integration components	Daml ledger API	· Provides details of sustainable bond over the life of the instrument to increase transparency while providing greater detail on the use of sustainable bond proceeds and impact of the underlying initiative · Connects users to the sustainable bond application utility and underlying blockchain infrastructure such as UPI and Octopus. · Conduct real-time KYC verification and authentication for retail investor's onboarding

Key Considerations

The integration of Mitigation Outcome Instruments (MOIs) into sustainable bonds offers a revolutionary approach to enhance the environmental impact, financial viability, and transparency of sustainable bond investments. MOIs, recognized under international or national verification processes in alignment with the Paris Agreement, are green house gas (GHG) emissions reduction or carbon credits thus linking the bond to tangible environmental outcomes.

Benefits of MOIs

a. For the issuer
- Access to more affordable financing through premium on MOIs
- Transitioning to an ex-ante carbon market structure to address financial viability gaps in green projects

b. For the investor
- Protection from reputational risks associated with greenwashing
- Opportunity to become familiar with the carbon market as an innovative investment avenue
- Use of MOIs for emissions offset and meeting targets
- Enhanced transparency regarding the environmental impact of sustainable bonds

c. For the sustainable finance ecosystem
- Ensuring additionality in sustainable projects
- Mitigating greenwashing risks and directing investments toward practical climate solutions
- Providing liquidity and price discovery to the carbon market

Traceability of funded environmental impact

- Leveraging Blockchain, smart contracts, and IoT solutions for real-time tracking and recording of mitigation outcome data
- Enhancing transparency in environmental outcomes compared to manual and cumbersome measurements, reporting, and verification processes

Efficient MOI redemption

- Utilizing blockchain technology for smart contract-based MOI delivery at maturity
- Automation reduces data reconciliation efforts among various parties, streamlining the settlement cycle and enabling atomic settlements for MOIs

Feasibility

CBDC integration
The project's integration with financial settlement through CBDC aligns with future trends in digital finance. This forward-looking approach not only enhances the project's appeal but also ensures its resilience in a rapidly evolving financial landscape.

Adoption of carbon credit protocols
The project draws from the successful POC demonstrated in the BIS Innovation Hub publication "Project Genesis", which has laid the groundwork for tokenization and carbon credit protocols, showcasing the feasibility of these concepts. By building upon the insights and achievements of Project Genesis, this project leverages a proven foundation to enhance transparency, objectivity, and environmental integrity in the green bond market.

Potential Benefits of Multi-Stakeholder Collaboration

POC demonstration
The successful prototype under BIS Innovative Hub "Project Genesis" showcased the vision of enabling retail investors to fund sustainable projects through digital bonds with full transparency into accrued returns as well as active environmental and social impacts over the project lifecycle.

Harmonization of data standards
Collaboration between the platform and sustainability data providers can align taxonomy frameworks and ESG reporting metrics strengthening consistency and integrity of the relevant disclosures.

Integrated infrastructure
Partnering with capital markets and carbon trading venues shall lay the foundation for exchange supporting mobilization at scale of private sector finance toward decarbonization.

Partnering with Deloitte
Deloitte launched the GreenLight Solution, a new decarbonization software tool aimed at helping organizations build emissions reduction strategies and a pathway to net zero emissions. This will assist sustainability capital issuing companies to build a complete picture of their roadmap, understand how to prioritize projects based on economics and time horizons, and update that view continuously as real-world conditions change.

By bringing together stakeholders from standard-setting bodies, financial institutions, regulators, and technology innovators, the platform fosters an ecosystem approach to drive:

- Demonstrable pathways for mainstreaming ESG investment
- Streamlined data protocols for robust impact measurement
- Liquidity and transactional linkages across sustainable finance landscapes
- This model of multi-party cooperation demonstrates most effectively how collective action can overcome barriers to attracting sustainable finance flows and channeling capital where it is needed most to tackle climate change.

Scope Boundaries

Tracking impact for Social Impact Bonds (SIBs)
While the project focuses on all ESG bonds, it will not include the capability to track the impact of Social Impact Bonds (SIBs) within its system. The project's depth of analysis and reporting for SIBs will be limited to a predefined set of impact metrics, and agency function shall be required to expand its scope to include the broader evaluation.

Issuer discretion for taxonomy
The project recognizes that issuers of green bonds may have specific criteria for determining the eligibility of green activities or assets. The project's scope includes providing flexibility for issuers to exercise discretion regarding taxonomy and eligibility criteria. However, this discretion will be subject to predefined minimum safeguards to ensure alignment with sustainability objectives.

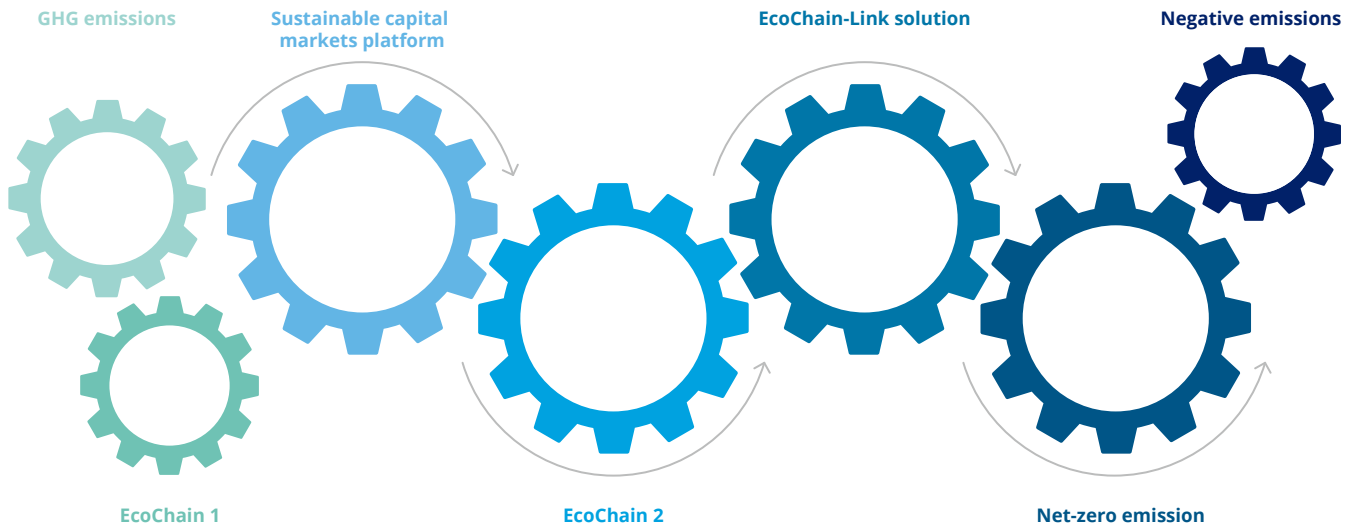
Agency due diligence for compliance
The project acknowledges the need for due diligence activities by regulatory agencies to confirm compliance with minimum safeguards and industry standards. While the project facilitates data access and reporting, its scope does not extend to conducting or overseeing the due diligence activities themselves.

EcoChain-Link

The figure below illustrates the key objectives of the EcoChain-Link:

Synchronized data flow	A synchronized and real-time data flow between emissions tracking and the sustainable capital markets platform. This ensures that emissions data generated in Ecochain 1 feeds directly into Ecochain 2 for use in financial products.
Dynamic carbon credits	Carbon credits generated from emissions reductions can be dynamically integrated into green financial products. This integration allows for the creation of financial instruments that not only support sustainability but also contribute to further emissions mitigation.
Enhanced transparency	EcoChain-Link enhances transparency by providing stakeholders with near real-time access to emissions data, financial transactions, and carbon credit issuance. This transparency is pivotal for building trust among investors, regulators, and the public.
Emissions-linked finance	By linking emissions data to financial products, EcoChain-Link enables a new era of emissions-linked finance. Investors can now make investment decisions based on the emissions impact of their portfolios further aligning financial markets with environmental goals.
Scalability and exclusivity	Designed with scalability and inclusivity in mind, the ecosystem can accommodate a wide range of participants, from individual investors to large institutions, thereby democratizing access to sustainable finance.
Reduction in greenwashing	Transparency standards and verification mechanisms are incorporated to reduce the risk of greenwashing. It ensures that green financial products are backed by genuine emissions reductions, and that investors can confidently invest in projects that make a real environmental difference.
Promoting additionality	The ecosystem encourages projects and initiatives that genuinely contribute to emissions reduction. EcoChain-Link verifies and quantifies the environmental impact of green projects ensuring that they go beyond business as usual, thus upholding the principle of additionality.

In essence, EcoChain-Link serves as the cohesive thread that weaves together emissions tracking and green finance.



EcoChain-Link represents the pivotal phase that connects and integrates the functionalities of the previous two EcoChains into a holistic and comprehensive ecosystem. It serves as the bridge that seamlessly links emissions tracking with green finance and creating a virtuous cycle of sustainability.

Our proposed comprehensive solution addresses two intertwined challenges: Tracking and mitigating carbon emissions linked to fossil fuels and meeting the growing demand for innovative green and sustainable financing. Our proposed solution leverages blockchain technology to create a carbon tracking mechanism seamlessly integrated with a sustainable capital market platform. This holistic approach aims to usher in a new era marked by transparency, efficiency, and inclusivity in the global fight against climate change while promoting sustainable finance on a universal scale.

Conclusion

In the face of an escalating global climate crisis, urgent action is required to combat climate change and reduce carbon emissions. International agencies have sounded alarm bells emphasizing the critical need to address rising temperatures and soaring carbon dioxide levels resulting from human activities especially the combustion of fossil fuels.

Our proposed comprehensive solution addresses two intertwined challenges: tracking and mitigating carbon emissions linked to fossil fuels and meeting the growing demand for innovative green and sustainable financing. Our proposed solution leverages blockchain technology to create a carbon tracking mechanism seamlessly integrated with a sustainable capital markets platform. This holistic approach aims to usher in a new era marked by transparency, efficiency, and inclusivity in the global fight against climate change while promoting sustainable finance on a universal scale.

The problem statement underscores the pressing issues faced by the global community from the lack of comprehensive carbon accounting and transparent emissions data to the need for standardized taxonomies and mechanisms to overcome barriers in sustainable finance. Greenwashing and insufficient traceability of environmental impact are obstacles that must be addressed to restore market credibility.

The objectives and scope of the proposed solution are ambitious but essential. The development of reusable smart contract frameworks and the deployment of a private blockchain network hold the potential to revolutionize carbon emissions tracking and green finance. By combining the transparency and immutability of blockchain with the real-time data provided by the IoT, we can create a robust system for monitoring and reporting greenhouse gas emissions across the fossil fuel value chain.

Simultaneously, the sustainable capital markets platform seeks to tap into the immense potential of sustainable investments through innovative financial products. By tokenizing green assets and integrating with traditional and digital payment systems, this platform paves the way for mainstream adoption of sustainable finance. The exploration of stablecoin and CBDC integration further positions it as a forward-looking and globalized solution.

The integration of the emissions ledger with smart contracts to automate the issuance of carbon credits adds a layer of efficiency and traceability to the process reinforcing the connection between carbon emissions and financial incentives.

In conclusion, the proposed solution represents a significant step forward in the battle against climate change and the promotion of sustainable finance. By harnessing the power of blockchain technology, the project aims to create a more transparent, efficient, and inclusive ecosystem that will benefit not only the environment, but also the global economy and society as a whole. The challenges are substantial, but the potential rewards are even greater as we work together to build a more sustainable and resilient future.

By combining the transparency and immutability of blockchain with the real-time data provided by the IoT, we can create a robust system for monitoring and reporting greenhouse gas emissions across the fossil fuel value chain.

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Endnotes

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