**Proposal: Developing a Blockchain-based and AI-assisted ESG Information System**

# Background

## The ESG megatrend and its significance to Hong Kong

ESG considerations have become a pivotal force in global investment strategies and corporate governance. Recognizing this megatrend is crucial for regions like Hong Kong to maintain their competitive edge. Hong Kong's financial market serves as a gateway between Mainland China and the rest of the world, positioning it uniquely to influence ESG practices regionally[1]. The Hong Kong Stock Exchange (HKEX) has mandated ESG reporting for listed companies, reflecting the growing importance of sustainable practices[2]. Strengthening ESG information infrastructures aligns with Hong Kong's strategic positioning as an international financial hub, with the goal of promoting sustainable finance and supporting the global transition to a low-carbon economy[3].

## Current challenges in ESG information disclosure and usage

Despite the growing emphasis on ESG, significant challenges persist in the disclosure and utilization of ESG information.

One of the primary issues is inconsistency and inaccuracy. The disparities among companies in ESG governance and disclosure practices often lead to inconsistent and sometimes misleading ESG information. This inconsistency may arise either intentionally or due to the absence of internationally recognized reporting standards, resulting in "greenwashing" concerns[3]. Additionally, ESG reports frequently lack completeness, omitting key indicators necessary for a thorough assessment of a company's sustainability performance[4].

While the above problem can be improved by the progress of ESG standardization, the verification of ESG data reported by enterprises becomes the most significant challenge. There is often a lack of transparent audit trails and standardized assurance processes, making it difficult to validate the authenticity of reported information[5]. When ESG data is utilized for investment analysis and decision-making, such problems become critical, potentially leading to misinformed investments and undermining the credibility of sustainable finance practices.

Furthermore, ESG data is frequently fragmented across various platforms and formats, complicating data aggregation and analysis for stakeholders[6]. Timeliness is another critical challenge. ESG disclosures are typically released on an annual basis, resulting in delays that hinder real-time decision-making for investors and regulators[7].

These challenges impede investors, regulators, and the public from making informed decisions, thereby limiting the effectiveness of ESG initiatives and undermining trust in sustainability reporting.

## Application of blockchain to address ESG challenges

Blockchain technology has been used in many applications, especially in financial contexts, due to its excellent features [8-12]:

* **Immutability:** Ensures data integrity by preventing alterations once data is recorded, reducing the risk of manipulation.
* **Transparency:** Distributed ledger allows authorized stakeholders to access and verify data, enhancing trust.
* **Traceability:** Enables end-to-end tracking of data provenance, crucial for verifying ESG claims.
* **Decentralization:** Reduces reliance on central authorities, increasing efficiency.
* **Automation:** Smart contracts facilitate automatic execution of predefined actions, improving efficiency in reporting and verification.

These features have significantly contributed to blockchain's prominence in financial applications, where data integrity, transparency, and efficiency are crucial[13]. Similarly, blockchain can potentially address the challenges in ESG information disclosure and utilization. By enhancing data accuracy and transparency, it can foster more reliable ESG practices and facilitate better decision-making for investors, regulators, and other stakeholders.

However, to effectively apply blockchain technology to the ESG context, adjustments and new developments are necessary to meet ESG's specific requirements, especially the integration of AI for data verification and analysis. Other examples include customizing blockchain platforms to handle the complex nature of ESG data, integrating advanced privacy measures to protect sensitive corporate information, and providing specific functions ensuring various needs of different stakeholders.

## Project proposal and deliverables

We propose to develop a blockchain-based, reliable, and AI-assisted ESG information system to leverage the strengths of blockchain and the latest advancements in AI technologies, with special enhancements vis-à-vis the needs of ESG practices, thereby improving the quality and reliability of ESG information and supporting cross-border sustainable finance practices.

The expected deliverables include:

* A ready-to-use ESG information system with a set of innovations in blockchain technology and AI applications.
* Academic publications and potential patents.
* International conferences and workshops.
* Potentially a startup for future commercialization.

This project will enhance data transparency and investor confidence, crucial for maintaining Hong Kong’s competitive edge. The potential commercialization and related academic contributions will further strengthen PolyU’s reputation as a world-class hub for digital finance and sustainability innovation. The implementation of this system can bring transformative benefits to the vast network of Mainland Chinese enterprises with close business ties to Hong Kong by providing a practical and advanced ESG information tool helping them meet international compliance standards, increase credibility in global markets, and attract more investment opportunities. With Hong Kong serving as a bridge between China and global financial markets, the platform will support seamless cross-border ESG reporting, empowering Chinese enterprises to improve their sustainability practices, thereby advancing both regional and global ESG goals and promoting sustainable growth in the Greater Bay Area and Yangtze River Delta.

# Further analysis

A thorough analysis of user requirements and technological limitations is essential for designing an effective ESG information system enhanced by blockchain technology.

## Functional and technical requirements for ESG information utilization

Different stakeholders have specific needs regarding ESG information. Key players include enterprises, investors, authorities, and the public. Understanding these requirements ensures the system serves all user groups effectively.

### Enterprises

Enterprises need solutions that allow them to report ESG data securely and comply with various regulations [14-16].

* **Reporting with data security:** Platforms to report sensitive ESG data without risking competitive advantage.
* **Compliance support:** Tools to ensure adherence to diverse regulatory requirements across jurisdictions.
* **Cost efficiency:** Any tool has to be economically feasible and rational to its benefit.
* **Data analytics:** Advanced analytics for internal assessment and strategy development.

### Investors

Investors require reliable and comparable ESG data to make informed investment decisions [17-19].

* **Reliable data access:** Immediate access to verified ESG data for decision-making.
* **Comparability:** Standardized data formats to facilitate comparisons across companies and industries.
* **Integrated risk assessment tools:** Integration of ESG data into financial risk models.

### Authorities

Regulatory bodies need efficient ways to monitor compliance and develop informed policies [20-21].

* **Regulatory oversight:** Real-time monitoring of compliance with ESG regulations.
* **Policy development:** Data-driven insights to inform policy and regulatory changes.

### Public

The public, including consumers, third-party service providers, or researchers, seeks transparency and engagement opportunities regarding ESG practices [22-23].

* **Transparency:** Access to ESG information to hold companies accountable.
* **Engagement:** Platforms for stakeholder feedback and participation.

## Limitations of current blockchain technology in ESG applications

While blockchain technology holds significant potential for enhancing ESG information systems, existing blockchain platforms have limitations that hinder their direct application in this context. Prominent blockchain technologies like Bitcoin, Ethereum, Hyperledger Fabric, Ripple, EOS, and others exhibit constraints in the following areas [24-37]:

* **Scalability issues:** Most existing blockchain platforms cannot handle the high transaction volumes required for ESG data without experiencing congestion and delays.
* **Energy consumption:** Platforms using PoW consensus mechanisms consume large amounts of energy, conflicting with ESG environmental objectives.
* **Data privacy:** Public blockchains expose transaction data, posing risks to sensitive corporate information.
* **Interoperability challenges:** Lack of standardization and compatibility with existing systems hinders integration.
* **Regulatory uncertainty:** Evolving legal frameworks and compliance challenges may pose risks.

Recognizing these limitations highlights the need for developing a customized blockchain solution tailored to the specific requirements of ESG applications. Such a solution should address scalability, energy efficiency, data privacy, interoperability, and regulatory compliance to effectively support ESG information systems.

# Proposal

Building on the above analysis, this proposal outlines a strategic plan to develop a blockchain-based reliable ESG information platform and its conceptual design of its architecture and its technical features.

## Strategy for building a reliable ESG information system enhanced by blockchain

To effectively develop a reliable ESG information system using blockchain technology, our strategy focuses on three key principles:

* Concentrate on core issues solvable by technology
* Align closely with real market practices for seamless integration
* Early engagement of key stakeholders
* Maximize the use of existing technologies to reduce development costs

By adhering to these principles, we aim to create a practical, cost-effective solution that addresses the most pressing challenges in ESG information disclosure and utilization.

### Concentrate on core issues solvable by technological innovation

The strategy begins by narrowing the focus to the core challenges in ESG reporting that can be effectively addressed through technological solutions. These core issues include:

* **Data integrity and immutability:** ensuring that esg data is accurate, tamper-proof, and trustworthy.
* **Data verification and traceability:** providing transparent audit trails to authenticate esg information.
* **Data accessibility and standardization:** making esg data readily accessible in standardized formats for analysis and comparison.

Focusing on these issues first is essential because they have a high impact on the reliability and usefulness of ESG data for all stakeholders. By addressing core challenges such as data integrity, verification, and accessibility, we directly enhance the quality of ESG information, which is crucial for investors, regulators, and enterprises. Additionally, these problems are technologically feasible to solve using blockchain technology due to its inherent features like immutability and transparency, making it well-suited for improving data reliability. There is also an urgent need for reliable ESG data to support informed decision-making in sustainable finance and to meet regulatory compliance requirements, underscoring the importance of prioritizing these issues.

## Conceptual design of a blockchain-based system for Reliable ESG Information

The proposed system addresses specific challenges and leverages blockchain features to enhance ESG information management.

### General concept

A diagram of a cloud with different symbols

Description automatically generated

Fig.1. General concept of Blockchain-based System for Reliable ESG Information

The Reliable ESG Information System is a blockchain-based platform designed to provide accurate, transparent, and verifiable data for various stakeholders, including enterprises, investors, regulators, analysts, and the public. At its core, enterprises provide their ESG data from multiple sources using secure data input methods like IoT and APIs. The blockchain records this data immutably, ensuring transparency and traceability. Advanced AI algorithms and smart contracts are used for data validation and verification, maintaining compliance and integrity. The data is then stored securely with multi-level access permissions. Stakeholders can utilize this verified data through customized dashboards, automated reporting tools, and analytics features for investment decisions, regulatory oversight, and sustainability assessments. The system enhances trust and facilitates informed decision-making, making ESG information accessible and reliable for all parties involved.

### Considerations addressing non-structured ESG information

ESG information includes both quantitative and qualitative descriptions of over hundreds of various topics; therefore, it is considered non-structured information. The ability to handle such non-structured data is crucial for the system to store ESG information. Standardized data formats fit for complex data structures and relationships are therefore necessary. Possible solutions include:

* **Data structuring protocols:** Implement standardized templates using languages like XBRL (eXtensible Business Reporting Language) for ESG data.
* **Ontology development:** Create an ESG ontology to map relationships between different data elements, enhancing interoperability[42].

### Automatic raw data collection with transparency, security and consistency

Collecting accurate data from the very beginning at the origin of the raw ESG data generation is key to ensuring the integrity and security of ESG data.

* **Automatic data collection/access**

Depending on the nature of various types of ESG data, the automatic collection of information may be carried out by different methods, such as **IoT Integration** (use IoT devices for real-time data capture (e.g., emissions sensors, energy meters) and **APIs** (Application Programming Interfaces for data input from enterprise systems.

* **Merkle Patricia Trie for data consistency**

Merkle Patricia Trie (such as Ethereum’s World State Trie) is a type of technogly which ensures data security and consistency by maintaining a tamper-proof, real-time representation of all account states and smart contract data.

A diagram of a business structure

Description automatically generated

Fig.2. “World State" in Ethereum [43]

When apply the Merkle Patricia Trie in the Reliable ESG information system, each ESG data provider’s information, such as sustainability metrics, carbon emission records, and governance scores, can be stored in Merkle Patricia Trie as a set of key-value pairs. Every time the data is updated (e.g., a company improves its environmental performance), the trie’s root hash is recalculated. Because each state change modifies the hash of its corresponding node and all parent nodes up to the root, even the slightest data alteration is immediately detectable. This property ensures data integrity and immutability, meaning that once the ESG information is stored, it cannot be changed without modifying the root hash. Recipients, such as financial institutions or regulators, can efficiently verify that the ESG data is consistent and has not been tampered with by simply comparing the root hash, providing transparent, reliable, and secure data management. This enhances trust in the ESG reporting process, ensuring that all stakeholders access consistent, verified information.

### Data authenticity, security, and transparency

Data security and privacy protection, which are core concerns for enterprises (data providers), can be ensured by several blockchain techniques.

* **Multi-level permission setting and access control:** Utilize a permissioned blockchain framework[44], with several levels of access permissions respectively for the authority, investors, and public, to balance transparency with data confidentiality.
* **Public and Priviate key cryptography:**

The public and private key cryptography will be used to ensure data security, authenticity, and integrity. Each entity (e.g., ESG data provider, financial institution, or regulatory authority) has a unique key pair: a public key (shared openly) and a private key (kept secret). When an ESG provider generates a data set (e.g., carbon footprint report), it is digitally signed using the private key, creating a digital signature that proves the data’s authenticity and the identity of the sender. This digital signature, along with the public key, allows recipients (e.g., financial institutions) to verify that the data has not been altered during transmission and originates from the claimed source. Additionally, for secure data transmission, the provider can encrypt sensitive ESG data using the recipient’s public key, ensuring that only the recipient’s private key can decrypt it, maintaining confidentiality. This mechanism prevents tampering, unauthorized access, and data fraud, thus building trust in the ESG reporting ecosystem and supporting compliance and transparency for all stakeholders involved.

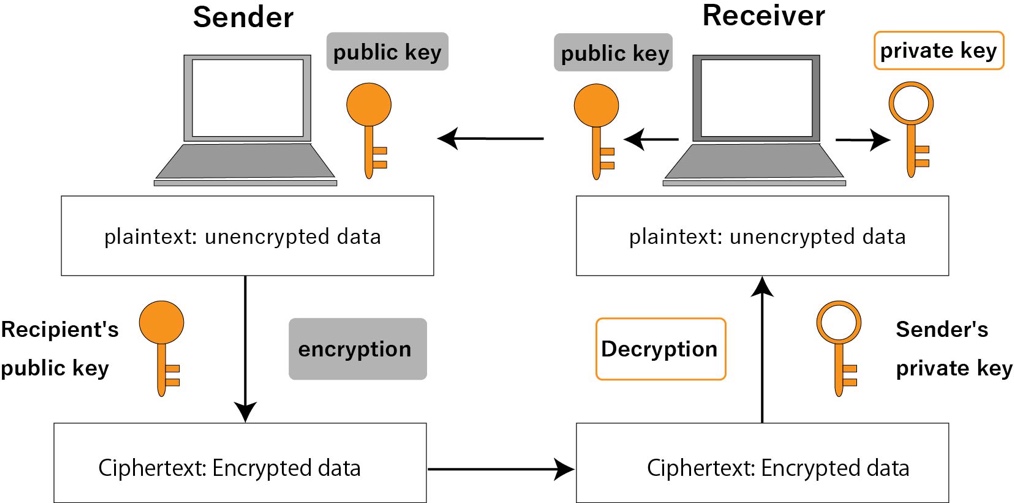


Fig.2. Public key and private key [45]

### Exploitation of data based on reliable ESG data and automation

On top of the reliable ESG database, various applications must be developed for specific use cases of each stakeholder to fulfill their operational needs. The process shall be "smart" and automatic to leverage efficiency.

**3.2.3.1 Automatic ESG report generation tool**

* **Smart Contracts:** Automate report compilation based on predefined criteria and data inputs.
* **Customization:** Allow enterprises to generate reports complying with different standards[.

**3.2.3.2 Automatic cross-border ESG report assurance**

* **Blockchain audit trails:** Provide immutable records for auditors to verify ESG data, enhancing trust.
* **Compliance modules:** Incorporate regulatory requirements from different jurisdictions into the platform.

**3.2.3.3 Real-time data analysis**

* **Analytics engine:** Integrate AI and machine learning algorithms for trend analysis and risk prediction.
* **Dashboard interfaces:** Offer customizable dashboards for different user groups, enhancing usability.

## Technical and Non-technical challenges

Besides the issues discussed in the above sections, there are still several important technical and non-technical challenges that must be thoroughly studied and addressed to ensure successful implementation and widespread adoption. These challenges span from technical limitations, such as scalability and data interoperability, to non-technical concerns, including regulatory compliance and change management.

### Technical challenges:

* **Scalability:** As the volume of ESG data increases and more users access the platform, scalability becomes a critical issue. High transaction volumes can lead to network congestion and slow processing times, limiting the system’s capacity to handle real-time data feeds. This can be addressed through layer-2 scaling solutions (e.g., sidechains and off-chain processing) and optimized consensus mechanisms to enhance throughput without compromising security or decentralization.
* **Interoperability:** For the system to be truly effective, it must seamlessly interact with various existing enterprise systems and ESG reporting platforms. Developing cross-chain protocols and standardized APIs for integration with diverse data sources and external databases is necessary to ensure compatibility and efficient data exchange.
* **Energy consumption:** The energy-intensive nature of some blockchain networks, especially those using Proof-of-Work (PoW) consensus mechanisms, poses a significant challenge. This high energy usage not only increases operational costs but also conflicts with the sustainability objectives of ESG practices. Addressing this issue requires exploring energy-efficient consensus algorithms such as Proof-of-Stake (PoS) and optimizing computational processes to minimize the environmental impact.
* **Token mechanism for engagement:** Designing an appropriate token mechanism to incentivize and reward enterprises and investors for participating in the platform is another technical challenge. The token system must balance encouraging engagement while avoiding excessive speculation or misuse. Developing a value-aligned incentive structure that ties token rewards to positive ESG contributions is essential.

### Non-technical challenges:

* **Regulatory compliance:** Although ESG data is considered as public data after disclosure, it often involves sensitive financial and operational information. **It is still unclear that whether the cross-border ESG data sharing and is entirely comply with relevant regulations on data privacy.** Ensuring the platform adheres to various local and international regulations (e.g., Data Security Law of the People"s Republic of China (2021)，EU General Data Protection Regulation [48] etc.) and industry standards while maintaining flexibility to adapt to future legal changes is crucial to reduce compliance risks.
* **User adoption:** The success of the platform depends on its ability to attract enterprises, investors, and regulators to use and trust the system. This requires not only demonstrating the value proposition but also addressing concerns related to data privacy, cost, and ease of use. An effective approach includes engaging stakeholders early, providing clear use cases, and showcasing the system’s benefits through pilot projects and demonstrations.
* **User-friendliness and data migration:** Ensuring that the platform is user-friendly and capable of facilitating smooth migration from existing databases is essential for adoption. The system must offer intuitive interfaces that align with current workflows and provide tools for efficient data migration to minimize disruptions and data loss. This will reduce the learning curve and make it easier for organizations to transition to the new platform.

By proactively addressing these challenges, the proposed blockchain-based ESG information system can deliver on its promise of enhancing data reliability, transparency, and usability while minimizing the risks associated with implementation and adoption.

## Risk and contreactions

The core risks associated with the development of the blockchain-based ESG information system and outlines key counteractions for each risk category.

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| --- | --- |
| **Risk** | **Key Counteractions** |
| **Technical Risk**  Inability to Overcome Technical Barriers such as scalability, data privacy, or interoperability issues, impacting system performance and functionality. | 1. Prioritize operational innovations instead of overweighting technical solution. |
| 2. Implement a phased development approach starting with an MVP to identify technical barriers early. |
| 3. Leverage existing frameworks (e.g., Hyperledger) to reduce custom development. |
| **Regulatory Risk**  Restrain on cross-border data transition Evolving regulations can impact the scope of the target market, or require significant redesigns and delay deployment. | 1. Engage regulators early to align with current and future expectations. |
| 2. Use a modular compliance architecture for easy integration of new requirements. |
| 3. Create a Regulatory Compliance Task Force to monitor legal changes and guide platform adjustments. |
| **Financial Risk**  High Initial development Costs may lead to budget overruns or project delays. | 1. Adopt a lean development model with core features. |
| 2. Implement milestone-based budgeting to control costs and allocate resources effectively. |
| 3. Seek cost-efficient resource (qualified students instead of professional developper) |
| **Go-to-Market Risk**  Low market adoption due to lack of awareness, trust, or perceived value. | 1. Launch targeted pilot programs with industry leaders to build credibility. |
| 2. Use targeted marketing and education campaigns to demonstrate value. |
| 3. Design incentive mechanisms (e.g., token rewards) to encourage participation. |

# Time Plan (3 years) and resource

## Implementation plan

|  |  |  |  |
| --- | --- | --- | --- |
| **Phase** | **Timeline** | **Description** | **Tasks** |
| **Step 1** | **0-3 months** | Identify and prioritize technological solutions for core issues | 1. Engagement of key stakeholders: Collect opinions and get support from the most important stakeholders. |
| 2. Assess Core Challenges: Focus on data integrity, verification, and accessibility. |
| 3. Select Appropriate Technologies: Choose existing blockchain platforms and tools that address these challenges. |
| **Step 2** | **4-12 months** | Core technology development and main system design | 1. Customize Blockchain Frameworks: Configure platforms like Hyperledger Fabric to meet ESG data requirements. |
| 2. Implement Standard Data Formats: Use XBRL or similar standards to structure ESG data consistently. |
| **Step 3** | **12-18 months** | Applications for market practices | 1. Data Entry Mechanism: Ensure a feasible method for data entry. |
| 2. Reporting APP: Ensure compatibility with IFRS and other frameworks. |
| 3. Data access API and analytical tool |
| 4. Focus on User Experience: Develop interfaces that are intuitive and require minimal training. |
| **Step 4** | **18-24 months** | Pilot the solution with industry partners | 1. Collaborate with Early Adopters: Work with companies already engaged in ESG reporting to test the platform. |
| 2. Gather Feedback: Use insights from pilot projects to refine the platform. |
| **Step 5** | **24-36 months** | Refinement, publication, and startup founding | 1. Refinement: Implement new improvements based on pilot project feedback. |
| 2. Publication: Produce academic research papers. |
| 3. Startup Founding: Establish startups to support the commercialization of the system. |

## Resource allocation:

### Personnel:

* + **Project Manager:** Oversee project execution and coordination.
  + **Senior researchers / experts:** Define project strategy, provide expertise and guidance of the researh/development, ensure the quality of the ourcome.
  + **Junior researcher / specialists:** conduct basic reserch and development taskes

### Budget

The budget will cover the following cost:

* + Human resource
  + Infrastructure and tools
  + Training and workshops
  + Application of relevant compliance certifications
  + Contingency funds

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