Enhancing Corporate Social Responsibility with Blockchain-based Trackable ESG Tokens

Yang R. Miranda[1], Paulo H. Alves[1], Ronnie Paskin[1], Rafael B. Nasser[1], Gustavo Robichez[1], Luiz Faria[2], Roberto Trindade[2], Joana Silva[2], Leandro Peixoto[2], Fernando Pellon de Miranda[2]

[1]Software Engineering Laboratory
Pontifical Catholic University of Rio de Janeiro (PUC-Rio)
Rio de Janeiro, RJ – Brazil

{yang,ph.alves,rpaskin,rnasser,robichez}@puc-rio.br

[2]Petrobras, Rio de Janeiro, Brazil

{larthur,robertoemery,joana_yglesias}@petrobras.com.br

{leandropeixoto,fmiranda}@petrobras.com.br

Abstract. *ESG is a sustainability framework promoting sustainability and responsible business practices relevant to Petrobras, a major Brazilian oil and gas company. In this sense, blockchain emerged as a technology for trustworthy information storage. This work demonstrates the ESG Token solution, built on top of EVM-compatible smart contracts to address data and process transparency, security, availability, and auditability. RBB (Brazilian Blockchain Network) was used to deploy the ESG Token smart contract, and the pluggable architecture allows for separating the blockchain layer from the business solution. Furthermore, ESG Token integrates with GovBR's digital signature platform, enabling self-declarations of validated identities to enhance accountability.*

1. Introduction

ESG stands for "Environmental, Social, and Governance", and it is a framework that aims to promote sustainability and responsible business practices [Pedersen et al. 2021, Gillan et al. 2021, Liu et al. 2021, Wu et al. 2022]. Many companies in the oil and gas sector face challenges with their environmental and social commitment mandates [Cardoni et al. 2019], including Petrobras, which is a major oil, natural gas, and energy company in Brazil. From the transparent and distributed ledger technology perspective *Blockchain* emerged as a technology that keeps information on a distributed network of computers, where data is stored in such a way that it is immutable once held by the network peers [Nasser et al. 2022]. The result is that this peer-to-peer ledger can be accessed without intermediaries, enabling trustworthy storage and retrieval of information.

By combining the public recording and immutability aspect of a blockchain with the registration of social investments made by Petrobras, our research aims at helping to fulfill its social mandates. The literature presents several related works regarding the ESG challenges and the use of blockchain technology to enhance transparency, availability, security, and auditing activities. However, to the best of our knowledge, none of them explored using a permissioned blockchain. Moreover, the Petrobras scenario offered challenges that required improvements on Ethereum smart contracts standards.

This work proposes a blockchain ESG Token developed on top of blockchain smart contracts to address data and process transparency, security, availability, and auditing activities. Furthermore, the tokens mirror the disbursements, allowing access to resources' current and historical statuses. Additionally, in this work, we explored the RBB (Brazilian Blockchain Network), a permissioned blockchain forked from the LACChain network [Allende López 2021] to deploy our smart contract following the Ethereum standards and providing adaptations to address Petrobras' requirements. As a result, we describe the developed solution and its pluggable architecture, which allows separating the blockchain layer from the system to allow, for instance, changing to another network, or operating in a centralized manner for maintenance activities.

Finally, this work depicts the ESG Token integration with GovBR's digital signature platform. GovBR is Brazil's governmental internet portal, which gathers services for Brazilian citizens[1]. ESG Token users can create self-declarations in the ESG Token system providing all expenditures and reports with a valid identity provided by GovBR. This integration enhances accountability and legal support since GovBR is a governmental organization.

The remainder of this work is organized as follows. Section 2 describes the basic concepts related to ESG, blockchain, and the oil and gas sector. Section 3 presents the related work. Section 4 defines the ESG Token solution, the connection with RBB as a permissioned blockchain, and the GovBR system to improve the accountability of the solution. Section 5 presents the discussion and the threats to the validity of this work. Finally, Section 6 presents our conclusions and future work.

2. Background

2.1. ESG

The ESG acronym was coined in the 2004 report "Who Cares Wins: Connecting Financial Markets to a Changing World", a joint initiative by 18 financial institutions from multiple countries, composed in response to a United Nations call "on how to better integrate environmental, social and corporate governance issues in asset management, securities brokerage services and associated research functions." The stated goals of the report were: (1) stronger and more resilient financial markets; (2) contribution to sustainable development; (3) awareness and mutual understanding of involved stakeholders; and (4) improved trust in financial institutions [Compact 2004, p.v] [Amel-Zadeh and Serafeim 2018].

ESG further expanded outside of financial institutions, into a framework for assessing how environmental, social and governance concerns are integrated into business models [Pedersen et al. 2021]. The primary goals of ESG are to promote sustainability and responsible business practices based on companies' environmental impact, social responsibility, and corporate governance practices [Gillan et al. 2021]. Empirical evidence suggests that state-owned firms, especially energy firms in emerging economies, are probably better positioned to handle environmental and social issues, even if there may be some disincentives for doing so [Gillan et al. 2021, p.7].

Developing an effective ESG solution can be challenging due to several factors.

[1]See "Assinatura Eletrônica do GOV.BR," Portal gov.br, Brazilian Government, updated March 10, 2023, `https://www.gov.br/governodigital/pt-br/assinatura-eletronica`)

First, ESG analysis relies heavily on the availability and quality of data related to a company's environmental, social, and governance performance [Wu et al. 2022]. However, this data can be challenging to obtain, inconsistent, and requires significant analysis resources. Second, lack of standardization is another challenge, since it can lead to inconsistencies in ESG ratings and rankings. Third, ESG analysis can be complex, requiring a deep understanding of a company's operations, supply chain, and governance practices. Balancing financial performance with ESG goals can be a challenge for investors and companies alike.

Thus, to promote sustainability, and environmental and social responsibility, a system must offer the following capabilities: (1) data and process transparency,; (2) data immutability, traceability, and availability; and (3) standardized processes [Cruz and Matos 2023]. Additionally, as an ESG solution may require interaction with many companies, processes and data must be available to all stakeholders, e.g., for auditing activities.

2.2. Blockchain

Blockchain is a type of distributed ledger technology (DLT). In this work, we will use the terms blockchain and DLT interchangeably. This technology uses cryptographic techniques to create a secure, distributed, consent-based, and transparent database. Information is stored in blocks of data that are linked together in a chronological and immutable chain. Once a block is added to the chain, it cannot be altered or deleted, providing a tamper-proof record of all transactions. As a result, blockchain enables peer-to-peer transactions without intermediaries, making it an ideal technology for creating secure and transparent systems for various use cases, such as digital identity, finance, and supply chain management [Paskin et al. 2020].

There are three types of blockchain networks, each with its own set of characteristics and tradeoffs: fully permissioned, public-permissioned, and permissionless, each with pros and cons depending on the purpose of its use [Nasser et al. 2022].

First, permissionless blockchains are open to anyone who wants to participate in validating or making transactions without any restrictions. This type offers high decentralization, transparency, and resistance to censorship, and prevents the risk of centralization [Paskin et al. 2020]. However, it has lower scalability and slower transaction speeds due to a large number of nodes.

Second, fully permissioned blockchains are private networks with limited access to specific users or organizations. This type offers high scalability, fast transaction speeds, privacy, and control over governance and decision-making [Alves. et al. 2021]. However, it has limited transparency and resistance to censorship, as only network members can verify transactions and control network specifications and participation.

Third, a public-permissioned blockchain is a hybrid of permissioned and permissionless blockchains, where access is restricted to some nodes while others are open to the public [Ibáñez and Moccia 2021]. This type of blockchain presents an increased decentralization compared to fully permissioned blockchains, which can improve security and reduce the centralization of power. Moreover, scalability is also a benefit if compared to permissionless blockchains due to the limited number of permissioned nodes,

which enable faster transactions. Thus, a solution architect should evaluate the business requirements before selecting a blockchain type for its system proposal.

Moreover, some blockchain technologies enable the execution of smart contracts, which are programming code that includes business logic in the execution process and can be deployed on a blockchain platform [Alves. et al. 2020]. Smart contracts enable complex transactions without intermediaries such as centralized servers, and they also allow for tokenization, where digital tokens can represent assets like currency, securities, and property.

Thus, blockchain technology has the potential to address ESG challenges by providing a transparent and tamper-proof record of a company's financial and social activities. By leveraging blockchain, companies can create an immutable ledger of their investments in ESG, providing greater transparency and accountability. This can be used to track a company's social impact, including its contributions to local communities, labor practices, and stakeholder engagement.

2.3. Oil and Gas Sector

ESG is a challenge for Oil and Gas companies, requiring careful selection and transparency in investments in Civil Society Organizations (CSOs)[2] or other entities; throughout this work, we use the term *Initiative* as a catch-all. Risks of reputational damage must also be mitigated through monitoring activities. Integrating ESG factors into investment decisions can potentially identify companies better positioned for long-term financial success and contribute to building a more sustainable and equitable global economy. This approach encourages companies to be accountable and responsible for their actions and consider the impact of their decisions on the environment, society, and governance practices.

Furthermore, Petrobras is a publicly-held corporation, majority-owned by the Brazilian government, operating in the oil, natural gas, and energy industry. This company develops over 60 social projects, impacting more than 40,000 people, especially supporting non-governmental organizations focused on: (1) sustainable development and local community autonomy; (2) early childhood development; and (3) professional energy-sector and innovation job training, especially for vulnerable communities. According to its social commitment mandates, it must measure and publicly disclose the social return of at least 50% of its projects until 2025 and keep an updated socioeconomic diagnostic of the communities around its centers of operation[3].

Thus, ESG considerations are important for the oil and gas industry, as they require careful selection and transparency in investments in CSOs and other entities. By integrating ESG factors into investment decisions, companies can identify those better positioned for long-term financial success and sustainability. The use of permissioned

[2]Although there may be substantial differences between NGOs (Non-Governmental Organizations) and CSOs, for the sake of simplicity we chose to consider them interchangeable as far as this work is concerned. A thorough discussion on the matter can be accessed in [Schoenefeld 2021].

[3]See "Petrobras website", Petrobras, updated March 10, 2023, `https://petrobras.com.br/en/about-us/profile/`, `https://transparencia.petrobras.com.br/institucional/sobre-petrobras`; "ESG: Environment, Social and Governance", Petrobras Investidores, Petrobras, updated March 10, 2023, `https://www.investidorpetrobras.com.br/esg-meio-ambiente-social-e-governanca/social/`

blockchain can further enhance transparency, security, and traceability in ESG-related investment activities, ultimately contributing to a more sustainable and socially responsible business environment, as well as a more equitable global economy.

3. Related Work

This section aims to present the work found in the literature regarding ESG, blockchain, and their applicability to the oil and gas sector. Moreover, it presents the literature gaps and how this work addresses them.

Junior et al. [Júnior et al. 2018] describe the Brazilian Development Bank (BNDES) Token, which is a token based on blockchain technology that allows tracking the resource allocation path among companies and NGOs. This token was built on top of Ethereum blockchain and its rules are described in a smart contract, which enables full transparency regarding the resource allocation rules. Unlike BNDES Token, in our approach, tokens can be exchanged between the oil and gas company and the NGOs. Moreover, we also add business rules that restrict the use of the tokens; for instance, only the project administrator can make disbursements (mirrored through the "mint tokens" method) and validate actions (through "burn tokens").

Lautert et al. [Lautert et al. 2020] propose using blockchain as an auditable, distributed, and secure storage to provide transparent data provenance without a third party involved. Although this is crucial to the ESG ecosystem, the authors focus on the performance aspects and do not apply their solution in a domain-based use case. Our work, on the other hand, proposes the use of blockchain technology in the ESG environment to enable distributed data provenance.

To demonstrate the blockchain applicability in the oil and gas sector the authors in [Nasser et al. 2020, Paskin et al. 2020, Alves. et al. 2021] proposed distinguished approaches to explore the major capabilities offered by such a technology. Although these architectures and use cases explored different types of blockchain in the oil and gas sector — permissioned and permissionless blockchains — the authors did not focus on tracking the expenses, which is a key point in the ESG environment.

Liu et al. [Liu et al. 2021] developed a blockchain-based framework to tackle the data authentication, consistency, and transparency gaps in current ESG reporting approaches. However, even though the authors concluded that the results contribute toward a reliable method for producing ESG reporting securely and transparently, they did not demonstrate a use case of its conceptual framework. Our approach was developed based on Petrobras's perspective and their experience dealing with multiple entities.

Wu et al. [Wu et al. 2022] propose a solution to allow companies to report their sustainable performance using an architecture of smart ESG, which is relied on the Internet of Things (IoT) and blockchain technologies. Their goal is to enable corporate crowdsensing for environmental data and improve transparency, traceability, and security of the ESG reporting process. However, the authors focused on environmental reporting and key performance indicators (KPIs). In this sense, our solution enables companies to track investments to outside organizations, such as NGOs, using blockchain to track all resource allocations.

Golding et al. [Golding et al. 2022] describe the Carbocoin, a token to represent

carbon emissions. The proposed solution allows ESG data to provide a holistic reputation score inclusive of ESG initiatives undertaken by market participants. However, the authors focus on the environmental variables, not the social investments, which are part of the ESG concerns. Our approach provides a solution that can also be used for social assets.

Jiang et al. [Jiang et al. 2022], explore the influence of Life Cycle Assessment (LCA) and blockchain on the ESG environment. The authors demonstrate the potential applications, and the proposed system automatically cross-validates ESG disclosures from companies of an entire value chain. Although the authors explored the permissionless blockchain model, other challenges in the ESG environment require privacy levels, i.e., not all data must be available publicly. Our work explores a public-permissioned blockchain to deal with this challenge.

The related work demonstrated the relevance of applying blockchain technology in the ESG environment. Most used blockchain and smart contracts to address transparency, traceability, and security. Through blockchain, companies can achieve data and process trust; however, the level and maturity of trust may vary according to the applied blockchain model. Furthermore, to the best of our knowledge, no related work has presented an approach exploring the public-permissioned blockchain model to financial tracking activities.

4. Blockchain ESG Token

4.1. Business Context

Initiatives are structured projects that receive funding from Petrobras. This funding is a matter of public interest. It is of paramount importance not only that this has as much transparency as possible, but also that the impact of these resources is duly tracked, particularly regarding the company's sustainability commitments.

ANP — Brazil's National Oil, Gas and Biofuels Agency — is responsible for calculating the distribution of these resources to the beneficiaries (Union, States and Municipalities) according to the apportionment criteria applied by the Agency. Moreover, ANP publishes consolidated special participation data on its web portal in reports (PDF and Excel files)[4]. It publicly discloses the resources paid by Petrobras and by other companies to their beneficiaries. This way, Petrobras' contribution is not evident, since it is bundled with others and not itemized for each oil field and special participation beneficiaries.

4.2. Proposed Solution

This work proposes a blockchain ESG Token system, which means to simplify the tracking of these payments. Analogous to a chemical tracer, the tokens mirror the disbursements, allowing access to current and historical statuses of resources. When connected to a blockchain, through a smart contract that controls fungible tokens (ERC-20 tokens), it effectively becomes a dApp (distributed application). Thus, the present research was developed to provide security, transparency, traceability, and scalability through this dApp.

[4]See "Agência Nacional do Petróleo, Gás Natural e Biocombustíveis," Portal gov.br, Brazilian Government, updated March 10, 2023, `https://www.gov.br/anp/pt-br/assuntos/royalties-e-outras-participacoes/participacao-especial`

In order to implement this solution, the ESG Token system uses blockchain technology as a basic infrastructure to support the creation, transfer, and burning of tokens in a transparent, distributed and secure network through previously established rules written in smart contracts. These contracts persist data in the blockchain, and the rules embedded in the smart contract algorithms ensure data integrity and proper governance of disbursements. The ESG Token system is a resource tracking system that can mirror financial transactions related to Initiative projects using tokens, whose operations (creating, transferring, and burning) can be recorded in an immutable, tamper-proof, and transparent way, which is compatible with multiple blockchain networks based on the Ethereum Virtual Machine (EVM) platform.

The architecture is designed so that the application communicates with an external blockchain through an existing smart contract on this network. The smart contract not only controls the business rules but also provides an immutable, independent, and auditable information storage. However, communication with the blockchain layer can be disabled if deemed necessary. This allows IT architectures to use a standard database technology rather than blockchain if needed. In this case, the company may not provide to companies stakeholders and Initiatives the same transparency, availability, auditability, and security as blockchain delivers.

Moreover, even then, the system will still use cryptographic signatures, allowing transactions to be authenticated with authorized users' wallets (keys). The system will operate in a centralized manner (offchain), but the key management and authentication will still be decentralized (Figure 1).

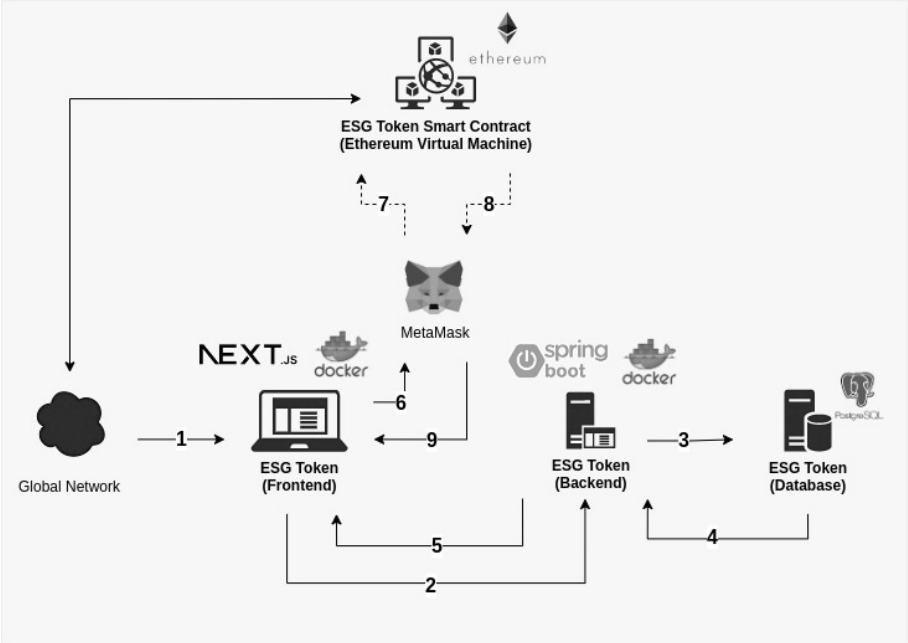

Figure 1. ESG Token Architecture

Thus, the ESG token can work in a hybrid fashion. It operates as a dApp when connected to a blockchain, or in a centralized manner with decentralized identities managed via a private/public key pair wallet (e.g., MetaMask[5]). Moreover, because of this

[5]MetaMask is a browser extension or mobile app with a key vault, token wallet, and other features. See

pluggable architecture, we can easily swap the connection to the blockchain layer to other EVM-based blockchain platforms.

So that the identity of the participants is duly authenticated, the system uses asymmetric cryptographic keys (public and private ECDSA key pairs[6]). Users are identified by their public key, and use their corresponding private key to ensure the origin and authorization of any transaction. System administrators, that also use their own keys for authentication, need only pre-register public keys and assign their roles, e.g., as the representative for an Initiatives project.

To confirm that transactions originated with legitimate users, cryptographic signatures of the transactions are generated on demand (by the wallet plugin itself, using the private key). The back-end receives these signatures and is able to confirm their origin by checking the public key, the content of the transaction, and the signature data. It then passes them on to the smart contract, which is also able to confirm the user origin, as well as the origin of the request, signed in turn by the back-end (with its own key), ensuring authentication of the entire chain of communication.

Some of the architecture's goals are scaling, minimizing, and centralizing operational costs. The system exposes these functionalities through an API using REST and HTTP protocols. This system is accessible from both inside and outside Petrobras, so that partner Initiatives can also access it.

In order to track the flow of disbursements, the smart contract layer implements and extends the ERC20 standard, a widely used framework for fungible tokens (Figure 2). The Hardhat development environment[7] was used to develop the contract. By using the framework and automated Typescript-based testing, it was possible to leverage the generated modules and use them to integrate the smart contract and the app.

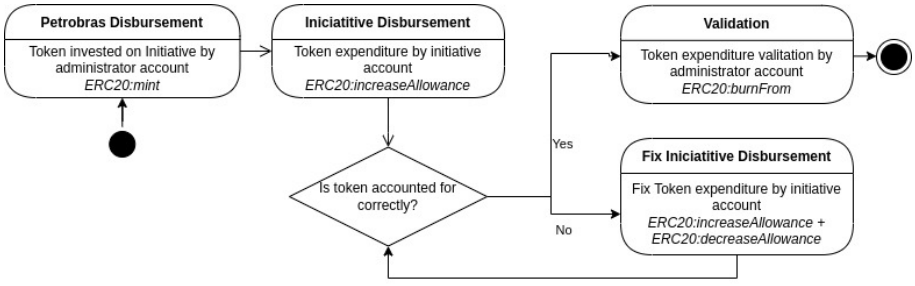

Figure 2. ESG Token Lifecycle

The implementation of this standard uses the smart contract interfaces made available as open source by Open Zeppelin framework[8]. Some interfaces have been adapted

"MetaMask Site," MetaMask.io, MetaMask (a ConsenSys foundation), updated March 10, 2023. `https://metamask.io/`)

[6]Elliptic Curve Digital Signature Algorithm, or ECDSA, is a Digital Signature Algorithm (DSA). Ethereum uses a Keccak sponge function, that can be used as a hashing function and authentication function as well as other uses. See "Team Keccak home page," Keccak. Team Keccak, updated March 10, 2023 `https://keccak.team/index.html`

[7]See "Hardhat home page," Hardhat, Nomic Foundation, updated March 10, 2023 `https://hardhat.org`.

[8]See "ERC20," OpenZeppelin Docs, OpenZeppelin, updated March 10, 2023, `https://docs.`

to allow multiple accounts enabled in the smart contract to have roles such as administrators or initiatives, in order to perform the appropriate transactions; it was a Petrobras' requirement. The methods available on the smart contract (including the ones extending the standard ERC20 interface) are:

AccessControl::addAdmin. Adds an Ethereum account as an administrator of the ESG Token smart contract. This role allows adding other administrator and initiative account users, as well as performing ERC20::mint and ERC20:burnFrom operations.

AccessControl::addCSO. Adds an Ethereum account as an Initiative operator, which can only perform ERC20::increaseAllowance and ERC20::fixIncreaseAllowance operations.

ERC20::mint. Used in transfers marked as a Petrobras Disbursement (*INVESTMENT*). It creates new tokens in the respective Ethereum accounts, i.e., mirrors the allocation of resources by Petrobras in the accounts referring to Initiatives. Alternatively, *ERC20::mintBatch* does the same, but in batch operations aggregating multiple transactions.

ERC20::increaseAllowance. Used in transfers marked as Initiative Disbursement (*EXPENDITURE*), it is executed by an Initiative account, allowing an enabled administrator to subsequently transfer the amount of tokens that were previously allocated to the respective Initiative account, as depicted in Figure 3. The analogous *ERC20::increaseAllowanceBatch* method does the same for a batch of such operations.

ESGToken::fixIncreaseAllowance. Used in transfers marked as Initiative Disbursement Correction (*FIX_EXPENDITURE*), combines the behavior of *ERC20::increaseAllowance* with *ERC20::decreaseAllowance* to undo a previous spend and make a new *ERC20::increaseAllowance*, used to correct an Initiative Disbursement value or metadata.

ERC20::burnFrom. Used on transfers marked as Validated (*CONCLUDED*), by an admin account who wishes to burn (destroy) validated tokens from an initiative account, decreasing their balance. The *ERC20::burnFromBatch* method allows batch burn operations.

The system was designed to consider users both internally and externally to Petrobras. An authentication flow was established based on digital signature validation, issued from the use of the Metamask digital wallet. The system has 2 user roles: (1) *Administrator role*, identified as "ROLE_ADMIN" in the system, assigned to Petrobras account managers; (2)*Initiative role*, identified as "ROLE_USER" in the system, assigned to the manager of an Initiative, a user that is external to Petrobras.

4.3. Digital Signatures

To extend the legal support of digitally signed actions, the system provides for self-declaration of responsibility regarding the safekeeping and use of Ethereum keys within the ESG Token application to users representing Initiative accounts.

This flow provides an integration with the digital signature system using GovBR's digital signature platform, so that the initiative's representative fills out a form in the ESG Token application, which will generate a PDF file containing various metadata, including the Ethereum digital signature of the complete message to be validated.

`openzeppelin.com/contracts/4.x/erc20`

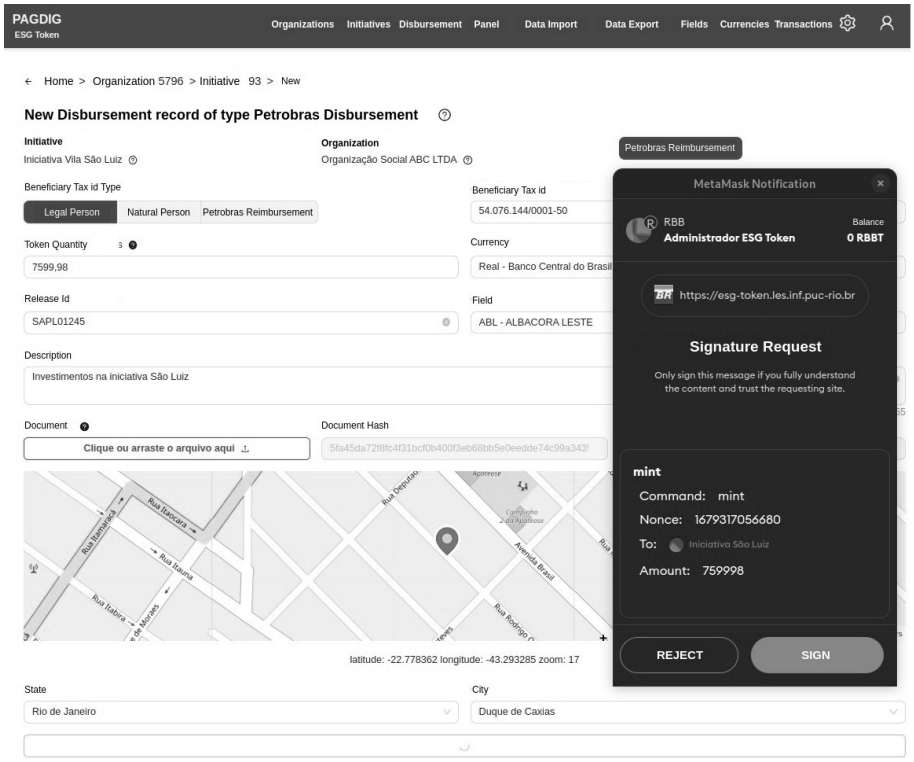

Figure 3. Example of a disbursement transaction from within the app, being signed with a MetaMask wallet.

For this, the user of the initiative profile account must log into the account, access the menu "Initiative Self-Declaration", and fill it in with the full name and CPF (i.e., "Natural Persons Register", an ID similar to a Social Security Number), as they have in their personal GovBR account. This process will generate and save metadata of the PDF that must be digitally signed via the GovBR platform. It is then validated against the GovBR digital signature, by the ITI verifier API[9] and the attached metadata validated against the Ethereum digital signature. Once in possession of the document version generated by the ESG Token, the user may then use the GovBR platform to execute the respective digital signature flow. This also requires the user to enable the GovBR application on the cell phone to obtain the 2-factor authentication code. This code is generated in the mobile application, and it is required by the platform to proceed with the signature.

In terms of validation, the file has the following metadata: Full name; CPF; Ethereum public key of the account referring to the initiative; Initiative name; CNPJ of the organization managing the Initiative; Full text of the self-declaration; Hash (keccack 256) of the full text of the self-declaration. When loading the file, a query is made to the ITI verifier API, which returns data on the validity of the digital signature, taking into account the parameters of the GovBR platform, and returns the full name of the individual who signed the document on the GovBR platform and part of the CPF. This data is compared and validated against the metadata present in the file and saved in the ESG Token API to validate the submission of the file to the platform.

[9]See "VALIDAR: Serviço de validação de assinaturas eletrônicas", Instituto Nacional de Tecnologia da Informação, updated March 12, 2023,`https://validar.iti.gov.br/`

4.4. The RBB Network

Initially, we chose the *RBB Network* — Rede Blockchain Brasil — for deployment and integration. Despite still being in the early pilot phase, it is a network of institutions with Brazilian national scope. It comprises a governance structure, and technological infrastructure forked from the LACChain network [Allende López 2021] aiming to facilitate the adoption of blockchain technology for applications of public interest.

This network proposes reducing costs and removing barriers to entry for the use of technology and innovation in the Brazilian public sector. RBB was founded by the Brazilian Development Bank (BNDES) and the Federal Court of Accounts (TCU), through a Cooperation Agreement, signed on December 4, 2022 [Burite et al. 2022, p.10; apud BNDES, 2022][Santos and Júnior 2022]. RBB is a public-permissioned network: "public" because it can be accessed by anyone, and "permissioned" because participating nodes with written permission need previous authorization to participate; as explained in Section 2, this type of network fills the gap between Public networks and Private Consortium networks, and

> *[...]combines the permissioning from private consortiums with a decentralized governance model, trying to achieve the best properties of both models. This is done in order to obtain features required for the implementation of many important use cases that can not fit in any of the other two models.* [Ruiz 2020].

Public-permissioned networks are a suitable solution for public interest applications, offering transparency and reliability like a public network, while at the same time keeping the lower cost and technological and regulatory challenges of permissioned networks.

In regards to its topology, RBB follows the same topology as LACChain[10]:

1. *Core validator nodes* are essential for the network to function, participating in the validation protocol and generating new blocks. They only connect to each other and to boot nodes.
2. *Core boot nodes* mainly connect validator and satellite nodes, but also allow setting up new nodes.
3. *Satellite writer nodes* are not essential for the network to function, but broadcast transactions to the network and can create private transaction channels.
4. *Core validator nodes* can only read the blockchain and only connect to boot nodes.

Finally, since PUC-Rio has a local *satellite writer node* at RBB, with low to no extra financial cost, it also contributes to expedited testing, development, and production deployment activities. It is also advantageous to actively participate in the early phases, so that actual use cases, such as the one presented herein, can help drive the construction and governance from a practical standpoint. In addition, it is based on EVM, which means that applications developed for this network can be replicated on other compatible networks also based on the Ethereum network with extreme ease.

[10]See "Topology", LACChain Documentation, LACChain, updated March 12, 2023, `https://lacnet.lacchain.net/topology/`

5. Discussion and Threats to Validity

Our research project ESG Token creates tokens that may be exchanged between the company (Petrobras) and Initiatives (such as CSOs). The tokens mirror disbursements between Petrobras and the Initiatives, as well as the latters' expenditures with their suppliers.

Extending a standard ERC20 implementation, token transfers are limited — enforced by the smart contract — in such a way as not to allow transfers between Initiatives, so that the token balance represents what has not been validated (i.e., accounted for, by presenting documented evidence of proper expenditures) until the validation occurs and the administrators allow the "burning" of tokens (or validation). In this way, an Initiative's balance is intended to always represent the amount yet to be accounted for and validated.

Instead of using a proprietary pattern, we opted to base our use cases on standard ERC20 operations and extend the implementation with some limitations as explained above. One of the advantages of such an approach is that it is fully compatible with wallets such as MetaMask, so that, for example, token balances will appear correctly simply by adding the smart contract's address. However, this also brings in some side effects, such as allowing only one key per Initiative. If the private key is lost, for example, there is currently no way to reset it, since the tokens are tied to that one key, and an administrator has no centralized authority over tokens transferred previously.

Although our project presents a real use case, with real disbursement data, mostly imported in batches, it is still not integrated with the daily work of Petrobras. Still, it has not yet been widely used outside of Petrobras, nor in a large quantity of smaller operations. Considering that blockchain is an emerging technology, we expect there may be misunderstandings by end-users as to how to use wallets. For example, there may arise difficulties in understanding how and when to properly issue token transactions. There may also be confusion as to how to properly safeguard their key, e.g., it is possible to export a private key. For security purposes, this exported private key must be safeguarded properly. This key and identity management may prove difficult in the future.

There may be unforeseen issues if the system is used by other entities that don't have the same policies as Petrobras. For instance, IT security policies may restrict browser extension management, affecting the MetaMask version directly. This requirement can impact the extension use and security, since there may be barriers to homologating new extension versions, or even the installation of the software itself on corporate computers.

6. Conclusion and Future Work

This work described the ESG Token solution and its architecture, which enable the solution connection with RBB, a permissioned blockchain network to deliver the blockchain capabilities. Even though RBB is in a laboratory phase, it is demonstrated to be capable of supporting the ESG Token solution and its transactions.

Moreover, our pluggable architecture proposal allows the blockchain layer to be changed, depending on the company's interests, for instance, to change to another network, or when the network suffers from instability or maintenance. Even when disconnecting from the blockchain, the key management and authentication will still be decentralized. However, by deciding not to use blockchain, the company may lower the

levels of transparency, security, availability, and auditing capabilities. Last, but not any less important, this work described the ESG Token integration with GovBR's digital signature platform to enhance accountability and legal support. By ESG Token, users can create self-declarations in the ESG Token system providing all expenditures and reports with a valid identity provided by GovBR.

For future work expanding this research, we would like to evaluate other public-permissioned blockchain platforms, such as Alastria and Sovrin, especially in regards to our pluggable architecture. Although ESG Token was homologated by stakeholders within Petrobras, since the development was based on the perspective of Petrobras as the research partner, it is natural to also consider analyzing the features and usability from the perspective of the Initiatives. Finally, we would also like to evaluate blockchain interoperability with other public-permissioned networks to enhance data availability and mitigate risks related the time-to-action, considering that RBB is currently in the laboratory phase.

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