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Master of Science By Research in
Electrical & Electronics Engineering

ΜΕΤΑΠΤΥΧΙΑΚΗ ΔΙΠΛΩΜΑΤΙΚΗ ΕΡΓΑΣΙΑ

στο πλαίσιο της Εκπόνησης Έρευνας με Επίβλεψη στο θέμα:

Τεχνολογίες κατανεμημένων καθολικών και ανταλλάξιμα τεκμήρια

Μεταπτυχιακός Φοιτητής : Δημήτριος Σταματάκης

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Master of Science By Research in
Electrical & Electronics Engineering

MSc Thesis

Supervised Research Project on:

Blockchain and NFTs

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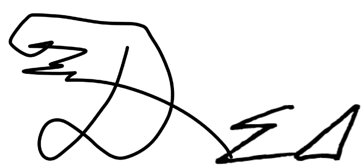

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ABSTRACT

The document begins with an extensive review of blockchain technology, delving into its core principles, applications, and evolution. The literature review also explores the integration of blockchain in the gaming industry, highlighting its transformative potential and emerging trends in blockchain games. The section establishes a theoretical foundation for the research, contextualizing the study within the broader blockchain ecosystem.

In the proceeding section, the authors present the innovative work carried out in creating a platform with three decentralized applications (DApps), a serious blockchain game, a rewarding application and a forum. The methodology outlines the design, development, and implementation processes, detailing the technological frameworks, tools, and approaches employed. A clear and comprehensive roadmap of the project's progression is provided, offering insights into the technical challenges and solutions.

The third section, furnishes a robust analysis of data collected from the 150 most popular blockchain games (at the time of writing) is presented, along with the results of a questionnaire distributed among users. The findings reveal key patterns, preferences, and dynamics in blockchain gaming, offering valuable insights into user behavior, game design, and market trends. The discussion contextualizes these findings, critically examining their implications and contributing to the broader understanding of blockchain gaming and their benefits.

Ultimately, the document concludes with reflections on the research, emphasizing its contributions to the field of blockchain gaming and serious game development. Recommendations are made for extending the research and enhancing the developed serious blockchain game. The conclusion underscores the potential of the study to inform future developments in blockchain technology, gaming, and education, paving the way for continued innovation and exploration.

KEYWORDS: Blockchain, Smart contracts, Blockchain games, Gaming, Serious games, Dapps, ERC tokens, gasless transactions, Blockchain platforms

ΠΕΡΙΛΗΨΗ

Το έγγραφο ξεκινά με μια εκτενή ανασκόπηση της τεχνολογίας blockchain, εισχωρώντας στις βασικές αρχές, εφαρμογές και εξέλιξη της. Η ανασκόπηση της βιβλιογραφίας εξερευνά επίσης την ένταξη του blockchain στη βιομηχανία των παιχνιδιών, επισημαίνοντας το μετασχηματιστικό της δυναμικό και τις εμφανιζόμενες τάσεις στα παιχνίδια blockchain. Η ενότητα θεσπίζει μια θεωρητική βάση για την έρευνα, τοποθετώντας τη μελέτη εντός του ευρύτερου οικοσυστήματος του blockchain.

Στην επόμενη ενότητα, οι συγγραφείς παρουσιάζουν το καινοτόμο έργο που πραγματοποιήθηκε στη δημιουργία μιας πλατφόρμας με τρεις αποκεντρωμένες εφαρμογές (DApps), ένα σοβαρό blockchain παιχνίδι, μια εφαρμογή επιβράβευσης και ένα forum. Η μεθοδολογία περιγράφει τις διαδικασίες σχεδίασης, ανάπτυξης και υλοποίησης, αναλύοντας τα τεχνολογικά πλαίσια, τα εργαλεία και τις προσεγγίσεις που χρησιμοποιήθηκαν. Παρέχεται μια σαφής και περιεκτική διαδρομή της προόδου του έργου, προσφέροντας επιστημονικές αναλύσεις για τις τεχνικές προκλήσεις και λύσεις.

Η τρίτη ενότητα, παρέχει μια ισχυρή ανάλυση των δεδομένων που συλλέχθηκαν από τα 150 πιο δημοφιλή παιχνίδια blockchain (κατά τη στιγμή της σύνταξης), μαζί με τα αποτελέσματα ενός ερωτηματολογίου που διανεμήθηκε μεταξύ των χρηστών. Τα ευρήματα αποκαλύπτουν κύρια πρότυπα, προτιμήσεις και δυναμικές στα παιχνίδια blockchain, προσφέροντας πολύτιμες πληροφορίες για τη συμπεριφορά των χρηστών, τον σχεδιασμό των παιχνιδιών και τις τάσεις της αγοράς. Η συζήτηση ερευνά αυτά τα ευρήματα, εξετάζοντας τις επιπτώσεις τους και συμβάλλει στην ευρύτερη κατανόηση των παιχνιδιών blockchain και των οφελών τους.

Τέλος, το έγγραφο καταλήγει με προβληματισμούς για την έρευνα, τονίζοντας τις συνεισφορές της στον τομέα των παιχνιδιών blockchain και την ανάπτυξη σοβαρών παιχνιδιών. Δίνονται συστάσεις για την επέκταση της έρευνας και τη βελτίωση του ανεπτυγμένου σοβαρού παιχνιδιού blockchain. Το συμπέρασμα υπογραμμίζει το δυναμικό της μελέτης να ενημερώσει τις μελλοντικές εξελίξεις στην τεχνολογία blockchain, τα παιχνίδια και την εκπαίδευση, διαμορφώνοντας τον δρόμο για συνεχή καινοτομία και εξερεύνηση.

ΛΕΞΕΙΣ – ΚΛΕΙΔΙΑ: Blockchain, έξυπνα συμβόλαια, Blockchain παιχνίδια, Κλάδος βίντεο παιχνιδιών, Σοβαρά παιχνίδια, Αποκεντρωμένες εφαρμογές, Τεκμήρια ERC, Συναλλαγές χωρίς κόστος καυσίμου, Πλατφόρμες blockchain

Ευχαριστίες

Θα ήθελα να εκφράσω τις βαθιές μου ευχαριστίες και την αμέριστη εκτίμηση προς όσους με συνόδευσαν και με υποστήριξαν στη διαδρομή της μεταπτυχιακής μου εργασίας. Η πολύτιμη βοήθεια και η αφοσίωσή σας ήταν καθοριστική για την επίτευξη των στόχων που έθεσα και αποτέλεσαν ανεκτίμητο παράγοντα στην εξέλιξη και ανάπτυξη των δεξιοτήτων και των γνώσεων μου.

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Συνεχίζοντας, θα ήθελα επίσης να εκφράσω τις ευχαριστίες μου προς την κυρία Νέλλη Λελιγκού, την καθηγήτρια μου, για την αδιάκοπη καθοδήγηση και υποστήριξη, καθώς και για τον χρόνο που διέθεσε για εμένα. Οι καθοδηγητικές της συμβολές, καθώς και ο τρόπος που αντιμετωπίζει και διαχειρίζεται τις διάφορες προκλήσεις και καταστάσεις, ήταν καθοριστικοί για την ανάπτυξη των δεξιοτήτων μου και τη βελτίωση της επιστημονικής μου κατεύθυνσης.

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Δ. Σταματάκης

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Best regards,

D. Stamatakis

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Introduction

In the rapidly evolving world of digital technology, blockchain has emerged as a transformative innovation, reshaping various sectors and redefining digital transactions. This thesis explores the multifaceted applications of blockchain technology, with a specific focus on its implications in the gaming industry, particularly in serious games designed for education or training. The research is part of the *GENERA project*, which endeavors to advance energy transition strategies within municipalities and boost the usage of monitoring tools dedicated to energy transition.

The *first section* provides an extensive literature review on blockchain technology. It traces the historical inception of Bitcoin, the evolution of blockchain through advancements like Ethereum's smart contracts, the Hyperledger project, and the global interest sparked by Facebook's Libra project.

The architecture of blockchain, including transactions, blocks, and its four primary layers, is explored in detail. Cryptographic techniques, classifications of blockchain networks, the decentralized nature of blockchain through its Peer-To-Peer (P2P) network, and consensus mechanisms like PoW, PoS, DPoS, PBFT and PoA are elaborated. Afterwards, the benefits of blockchain-powered games, their architectural framework, the concept of tokenization, the most common blockchain token standards and many more vital concepts are mentioned and analyzed.

The *second section* outlines the methodology employed in this study. It details the overall design of the GENERA platform, including the specially made private blockchain network, the serious blockchain game and another two Decentralized Applications (Dapps).

The one is called *"Rewarding Tool"* and it created as a way to motivate users to explore and interact with the platform's web services and applications. This Dapp features its own crypto currency, named MyGreenScore (MGS), which can be used to redeem various rewards offered by the project's contributors. The other is the *"Social Forum"*, in this Dapp user can express their ideas on a variety of subjects generated by the group of administrators who oversee it. By posting, commenting or voting users are provides with the opportunity to claim MGS tokens.

The *third section* delves into the analysis and findings of the current research, the employed research methodology and the research approach. It consists of three subsections, the first provides an analysis of data gathered from the 150 most popular blockchain (July 2023). The second explores the obtained responses from a survey constructed to study the public's perspective of the blockchain technology and procure feedback regarding the developed serious blockchain game. Finally, the last subsection provides a comprehensive examination of the following research questions:

1. What advantages does blockchain technology offer to the gaming industry?
2. How do these advantages enhance serious games, whose primary objective is to educate or train?
3. How does the inclusion of blockchain technology in the proposed game boost players' comprehension and involvement?

The final section encapsulates the conclusions drawn from the study, synthesizing the key findings, discussing their implications, offering recommendations for future research and practice, and reflecting on the limitations of the study. The authors believe that modern AI generative tools can be employed to solve the majority of the discovered issues concerning the developed game.

Through this research, the thesis aims to shed light on the multifaceted applications of blockchain technology, particularly in the context of serious games. By exploring the complex relationship between technology, gaming, and education, this thesis offers valuable insights that contribute to both academic and industry knowledge. The insights derived from this study are expected to foster a broader understanding of blockchain's applications and its future implications in various domains. It serves as a comprehensive guide for researchers, practitioners, and enthusiasts interested in the intersection of technology, gaming, and education.

Section 1:
Literature Review

1.1. Blockchain Technology

In 2008, Bitcoin's inception, an idea crafted by Satoshi Nakamoto, signaled an unprecedented milestone in the world of digital currency. Since that time, the foundational blockchain technology has captured attention across the globe, with its applications extending into sectors such as agriculture, education, sports, and governmental affairs [1].

Ethereum [2] represents one of the most significant advancements in blockchain technology, introducing the novel concept of smart contracts. These programmable contracts on the blockchain facilitate Ethereum in functioning as a medium for currency exchanges. Both Bitcoin and Ethereum fall under the category of public blockchains, allowing anyone to enter the network and take part in its operations.

In the year 2015, the Hyperledger project was initiated by the Linux Foundation as an open-source blockchain venture [3]. In contrast to Bitcoin and Ethereum, which are public without authentication protocols, Hyperledger is identified as an enterprise blockchain, tailored explicitly for large-scale business applications and gives distinct roles and permissions to each member. Moreover, it bypasses the energy-consuming process of mining, a characteristic of Bitcoin, resulting in enhanced efficiency.

The 2019 launch of Facebook's Libra project white paper revitalized the global interest in cryptocurrencies, drawing the focus of investors and scholars towards the field of blockchain. Among the myriad applications of blockchain technology in both public and private domains, a particularly striking usage is found in the realm of digital governance. Termed as Web 3.0, countries worldwide are leveraging this new era of the information revolution using blockchain technology, thus encouraging the rapid advancement of industrial innovation and evolution, and shaping enduring policies, laws, and public attitudes towards this avant-garde technology.

1.1.1. Architecture

1.1.1.1. Transactions

A blockchain transaction represents the documentation of the exchange of information or value between two or more parties [4]. This process involves the trading of digital commodities like cryptocurrency across a decentralized network. Initially, the transaction is confirmed by the network's stakeholders, known as nodes, and then it is securely encapsulated within blocks.

1.1.1.2. Blocks

The blockchain employs a data structure known as a "block." Blocks are comprised of two main components: the body, or the data, and the header [4]. They are sequentially connected through cryptographic links, aligning in a linear pattern to form what's referred to as a chain of blocks, hence the technology's name.

Contained within the body of a block is an assembly of transactions or the specific data designated for permanent storage on the blockchain. The header, on the other hand, accommodates the block's metadata. Though various blockchain platforms might differ in their implementation of block architecture, the subsequent properties are generally regarded as the most crucial and commonly utilized.

- Previous Block Hash/Address (Serving as the block's unique identifier or fingerprint)
- Time of Block Creation (Recorded in Unix epoch format)
- Nonce (A random 32-bit figure employed by nodes to facilitate the addition of new blocks)
- Merkle Root (A hash encapsulating all the transactions within the block)
- Height (Representing the total number of blocks that have been mined)
- Difficulty (An indication of the challenge associated with mining a specific block)
- Number of Transactions (The quantity of transactions housed within a particular block)

1.1.1.3. Layers

Figure 1 offers a detailed depiction of the complex structure of blockchain technology, dividing the architecture into four fundamental layers: infrastructure, platform, distributed computing, and application.

The infrastructure layer incorporates the essential hardware components required to operate the blockchain system, including nodes, storage, and networking facilities. Nodes form the building blocks of the network and come in three variations: simple nodes (or light nodes), full nodes, and mining nodes.

Simple nodes are limited to sending and receiving transactions without the ability to store or validate the ledger, while full nodes have these capabilities. Mining nodes, also referred to as block creators, are a type of full node that has the additional function of mining, or the formation of new blocks. The storage aspect is devoted to housing the ledger that contains all transaction records.

The platform layer facilitates communication among network participants through Remote Procedure Calls (RPC), web Application Programming Interface (API), and REpresentational State Transfer (REST) APIs.

In the realm of blockchain technology, the **distributed computing layer** ensures the protection of local data access, sustains fault tolerance, guarantees the unchangeability of transaction logs, shields privacy, authenticates validity, and secures transaction-related information. One key feature, immutability, solidifies the permanent nature of updates to the ledger. The blockchain network utilizes a consensus protocol to achieve collective agreement on transaction sequencing, ledger updating, and miner selection for the creation of the subsequent block. This layer is also pivotal in authenticating users via encryption methods [5] and maintaining data privacy through hashing techniques [6].

Finally, **the application layer** houses the business rules governing the transfer of digital commodities and the implementation of smart contracts. Clients can access these through the platform layer. Also situated within this layer are decentralized applications, or DApps, driven by smart contracts.

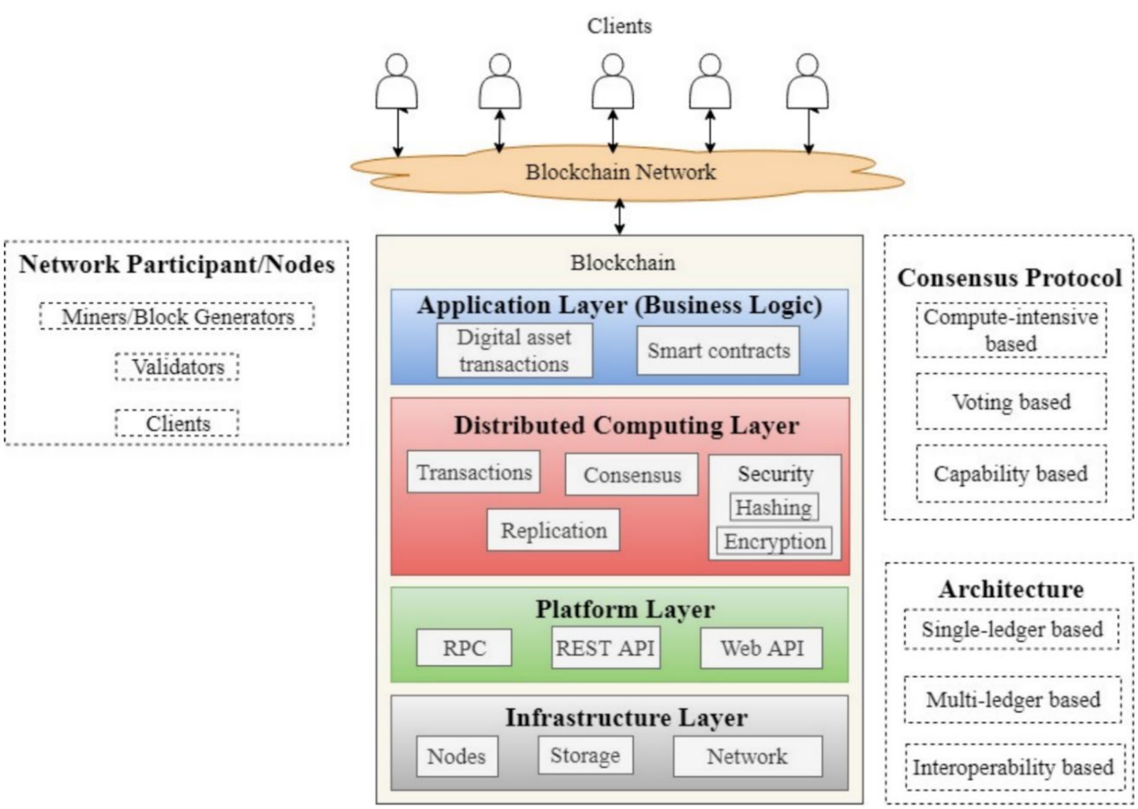

***Figure 1**: The Layers of a Blockchain. Source: [4], p.4. Obtained: (15 April 2023)*

1.1.2. Cryptography

1.1.2.1. Hashing Algorithms

A **hash function**, sometimes referred to as a hash algorithm, is a mathematical operation that takes data of an arbitrary size and converts it into a fixed-size output known as a "hash." Within the framework of blockchain, hash functions play a pivotal role in securing the data's integrity, immutability, and safety.

Every block in a blockchain encompasses several transactions, and the current block stores the hash of its predecessor. This structure establishes a tamper-evident record of all transactions. Should someone attempt to alter the contents of a block, the associated hash would be modified, causing this change to ripple through all succeeding blocks in the chain. This alteration makes any tampering immediately detectable since the affected blocks' hashes will no longer align with the original hashes documented in the blockchain.

In addition to ensuring integrity, hash functions contribute to privacy and confidentiality. By translating sensitive information into a hash, the original data itself doesn't need to be stored on the blockchain. This transformation permits transaction tracking without exposing the underlying confidential information. Furthermore, hash functions are instrumental in the "mining" process for Proof-Of-Work consensus protocols, such as the one utilized by Bitcoin. In this process, network nodes vie to solve a cryptographic puzzle founded on a hash function. The victor of this contest gains the privilege of appending the subsequent block to the blockchain and receives cryptocurrency as a reward.

1.1.2.2. Asymmetric Encryption

Asymmetric Encryption, also known as Public Key Cryptography, is a cryptographic method that utilizes a pair of keys, namely public and private keys, to encrypt and decrypt messages [7]. Within the sphere of blockchain, this type of encryption is crucial in maintaining the security and privacy of transactions. When a user wishes to send a transaction, the information is encrypted using the recipient's public key. The recipient can then decode the message with their private key, accessing the transaction data. This guarantees that even if someone intercepts the transaction details, they remain unreadable without the corresponding private key.

In addition to its role in securing transactions, asymmetric encryption is instrumental in authenticating users within blockchain networks. The public key serves as a distinct digital identifier for a user, and a digital signature, generated with the private key, verifies the user's identity. Through this mechanism, asymmetric encryption helps prevent unauthorized access to the blockchain, ensuring that only those with proper authorization can engage in the activities of the network.

1.1.2.3. Encryption utilizing Elliptic Curve

Elliptic Curve Encryption, a form of asymmetric cryptography, carries significant importance in the field of blockchain technology [7]. This technique involves creating a public and private key through a specific mathematical equation referred to as an elliptic curve. The public key is used for encrypting data, while the private key serves to decrypt it.

In blockchain applications, elliptic curve encryption is notable for its combination of security and efficiency. Distinct from traditional encryption methodologies, elliptic curve encryption requires the use of considerably smaller keys, resulting in quicker encryption and decryption processes. Moreover, the mathematical complexities associated with elliptic curves make it a considerable challenge for unauthorized individuals to break the encryption. This lends elliptic curve encryption as a trustworthy choice for blockchain transactions, particularly when strong security safeguards are essential.

1.1.3. Blockchain Classifications

Networks employing blockchain technology can be categorized into 3 main types based on:

- Data accessibility [8]
- Network participation [9]
- Smart contract compatibility [10]

1.1.3.1. Data accessibility

Data accessibility in the context of blockchain refers to the capability to have the right to read or write information within the network. This broad category can be segmented into four distinct subcategories:

- **Public Blockchain**. This type of blockchain operates on an open-access principle, granting the ability to read and submit transactions to anyone who wishes to participate.
- **Private Blockchain**. In this configuration, the rights to read and enter transactions are confined solely to a specific organization or all affiliated entities within a larger corporate group.
- **Community/Consortium Blockchain**. This particular version of blockchain technology brings together a consortium or group of multiple organizations. These entities collectively have the ability to submit transactions and examine the transactional information within the network.
- **Hybrid Blockchain**. This innovative category blends the characteristics of Public, Private, or Community/Consortium Blockchains, providing a versatile means to handle transactions. The concept of Hybrid Blockchain has emerged, allowing the configuration of a blockchain platform in multiple modes, thereby granting unparalleled flexibility and adaptability in transaction facilitation.

1.1.3.2. Network participation

Participation within the context of blockchain refers to the act of engaging in the verification procedure that leads to the creation of new blocks. Different types of blockchain systems define distinct levels of participation:

- **Permissionless Blockchain**. Under this blockchain model, participation is open to all, allowing any entity to join the verification process and contribute to the network by leveraging their computational resources. No prior authorization or permission is needed to engage in this decentralized, inclusive system.
- **Permissioned Blockchain**. In this version, participation is more controlled, limiting the ability to read and submit transactions exclusively to a specific organization or to all affiliated entities within a common corporate structure. This ensures that only authorized participants can take part in the verification and validation processes.
- **Hybrid Blockchain**. Participation in this form of blockchain requires pre-obtained permission or approval. Access to the network is confined to authorized participants, who are deemed qualified to operate nodes for the purpose of validating and verifying transactions.

1.1.3.3. Smart contract compatibility

This classification is grounded in **the ability of the blockchain to facilitate smart contracts**, or more specifically, if it encompasses a Virtual Machine (VM) capable of executing operation codes and retaining state variables:

- **Stateless Blockchain**. In this type of blockchain architecture, the emphasis is placed solely on optimizing transaction processes and confirming their legitimacy through the calculation of hashes. The system functions independently from the smart contract logic layer, making it impervious to any weaknesses or defects that may exist within the underlying smart contract code. The absence of state management makes it simpler but limits its applicability for complex transactions.
- **Stateful Blockchain**. This variant of blockchain comes equipped with integrated smart contract functionality and computational capabilities for transactions. Moreover, it supports a wide variety of business logic, enhances its operational efficiency, and sustains persistent logical states. This approach allows for more complex transactions and contracts, creating a versatile environment for various applications.

1.1.4. Peer-To-Peer (P2P) Network

A decentralized communication framework, known as a peer-to-peer (P2P) network, consists of interconnected nodes or peers capable of directly exchanging information without the need for central intermediaries.

In the context of blockchain technology, P2P networks hold significant relevance as **they foster a secure and distributed mode of information exchange among the participants**. Unlike a centralized system, transactions within the blockchain are authenticated and processed by a network of peers, enhancing the system's security and making it resistant to unauthorized alterations.

The P2P structure in blockchain technology **negates any single points of failure [11]**, as each node within the network holds a duplicate of the entire blockchain, permitting the autonomous verification of transactions. This decentralized approach **augments transparency and diminishes the likelihood of censorship** or undue manipulation by any one controlling entity [11]. Summarizing, the peer-to-peer network architecture is instrumental in sustaining the dependability and integrity of blockchain systems, reinforcing its core principles of decentralization and security.

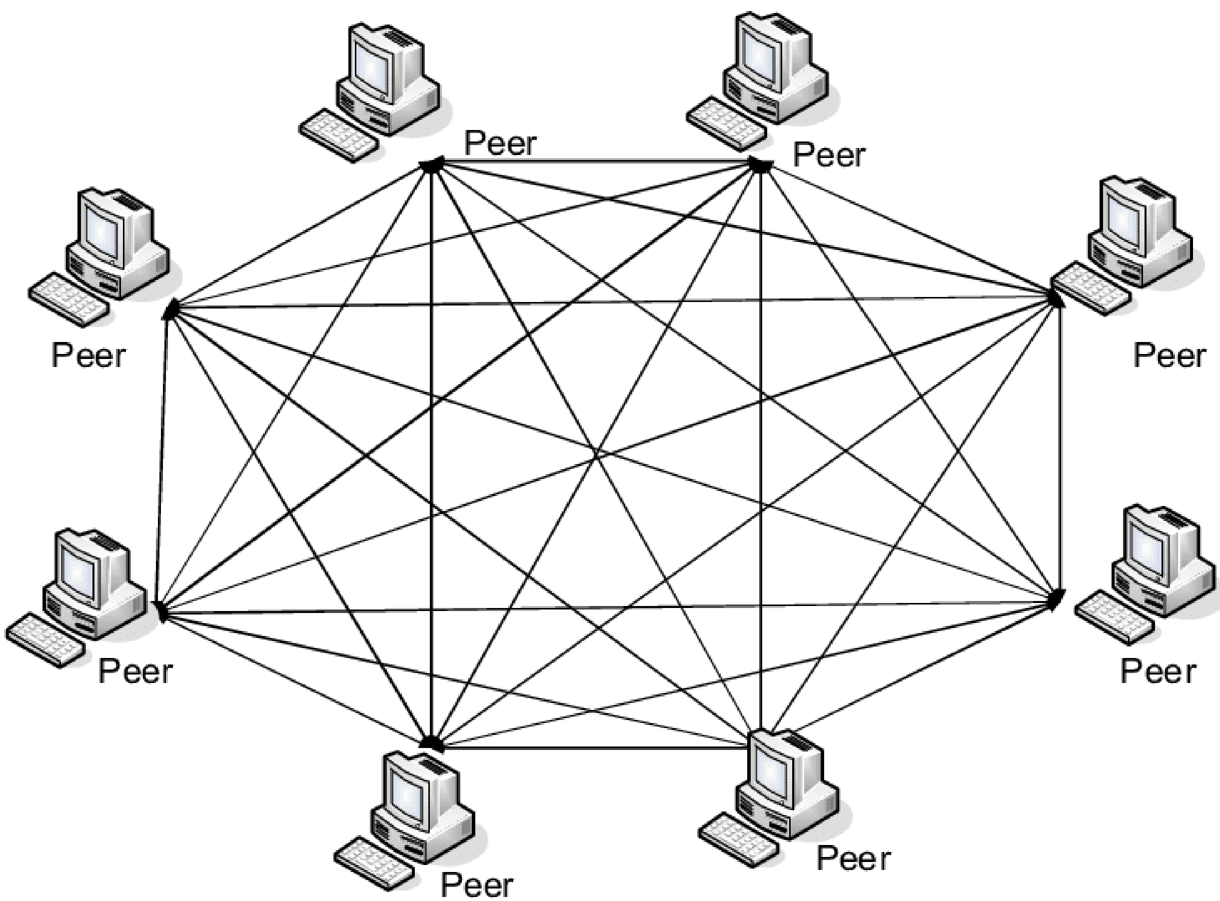

Figure 2**: A simple Peer-To-Peer Network. Source: **[12].

1.1.5. Consensus Mechanisms

Consensus mechanisms **serve as the vital core of a blockchain network**, functioning as protocols that **validate and facilitate agreement on the ledger's status**. These mechanisms manifest in diverse forms, each possessing unique attributes, strengths, and weaknesses. However, they share several critical characteristics in common [13].

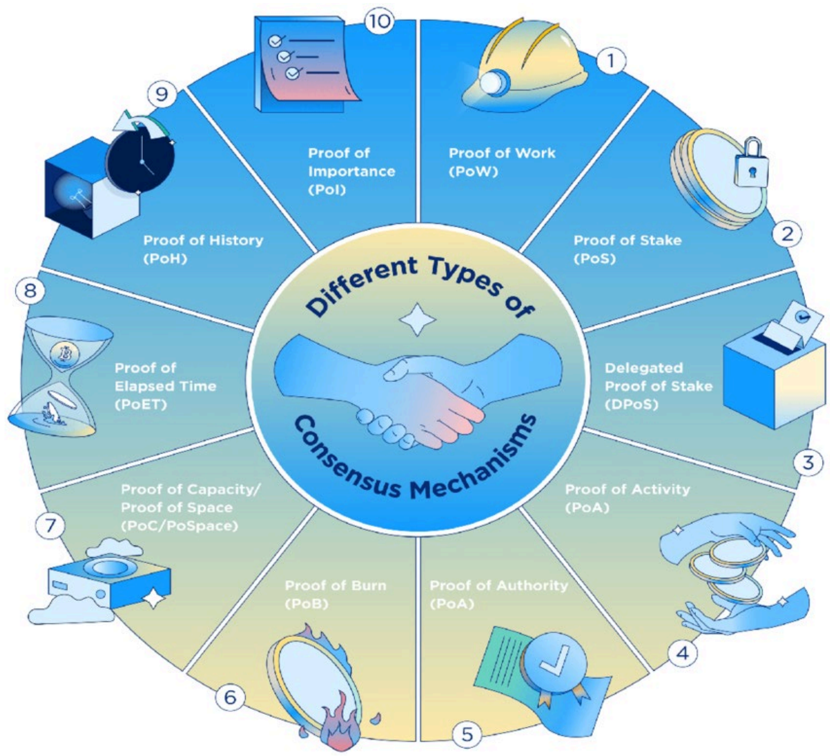

Figure 3*: Popular Consensus Mechanisms. Source:* ***[14].***

1 **Concordance on the Ledger's State:** The fundamental goal of any consensus algorithm is to guarantee that the network's nodes reach a unified understanding of the ledger's state, which encompasses the sequence and legitimacy of transactions.

2 **Prevention of Double-Spending:** In the context of decentralized structures, a significant concern is the prevention of tokens or digital assets from being utilized more than once. Consensus mechanisms play an essential role in thwarting double-spending by confirming that only authorized transactions become part of the ledger.

3 **Resilience to Failures:** Consensus algorithms are crafted to exhibit fault tolerance, signifying that the network remains functional even if certain nodes become defective or are breached.

4 **Resistance to Sybil Attacks:** For the maintenance of network safety and equilibrium, consensus algorithms must be impervious to Sybil onslaughts, where a malefactor generates numerous counterfeit identities to subvert the system.

5 **Scalable Nature:** With the growth of nodes and transactions within a blockchain network, it's crucial for the consensus algorithm to be adaptable, capable of managing an escalating volume of nodes and transactions with efficacy.

The following are the most prevalent consensus models:

Proof of Work (PoW) [13], represents a cryptographic technique within blockchain to sustain the ledger's wholeness and substantiate transactions. This method involves nodes, known as "miners," vying to solve intricate cryptographic puzzles, allowing them to add new transaction blocks to the blockchain. The triumphant miner is rewarded and granted the right to attach the block to the chain. PoW establishes a sturdy security framework, making it demanding for any individual to modify the blockchain's state without bearing substantial computational costs, thus strengthening the system's security and dependability.

Proof of Stake (PoS) [13], operates as a consensus model in blockchain to verify transactions and strengthen the network. Unlike PoW, where "miners" compete in solving computational riddles, PoS hinges on validators that secure a fixed amount of the blockchain's native currency. Validators are chosen based on their stake size to substantiate transactions and add new blocks. The higher the stake, the more likely the node is chosen as a validator. PoS fosters a more energy-conserving process compared to PoW and minimizes the hazard of a 51% attack, making it a more eco-friendly and scalable alternative.

Delegated Proof of Stake (DPoS) [13], is a consensus algorithm employed in the blockchain domain to assure the veracity and legitimacy of transactions. Here, token owners have the right to vote for specific "delegates" responsible for validating transactions and appending blocks to the blockchain. This setup is more efficient and scalable compared to traditional PoS and PoW, due to a limited number of validation nodes. Moreover, DPoS integrates incentives for delegates to comply with the network's requirements, and they can be voted out if they perform inadequately. This voting mechanism ensures a more equitable and distributed governance structure**.**

Practical Byzantine Fault Tolerance (PBFT) [13], is applied to guarantee data accuracy and block false information within a dispersed system. PBFT is configured to endure the existence of erroneous or hostile nodes, achieving consensus even amidst node failure. Within this framework, every node keeps a local copy of the blockchain, and consensus is reached via a voting process, needing a majority of nodes to concur on a transaction's validity before it's added. This mechanism attains substantial fault tolerance by mandating a supermajority agreement, hindering malicious nodes from disrupting the system's regular functionality.

Proof of Authority (PoA) [13], is a consensus algorithm that plays a vital role in some blockchain networks, particularly those that prioritize identity and reputation over computational resources. In the PoA model, transactions and blocks are validated by a pre-approved set of nodes, known as "authorities" or "validators," whose integrity and authority are established based on their identity and reputation. Unlike PoW and PoS, PoA doesn't require complex cryptographic puzzles or staking of assets. Instead, it relies on the validators' known identity and trustworthiness to make decisions about the validity of transactions.

This streamlined approach tends to provide faster transaction times and greater scalability, making PoA an appealing option for private and consortium blockchains where all participants are known and trusted. Additionally, since validators are known and must follow well-defined criteria for validation, the system minimizes the risk of malicious behavior, aligning the validators' incentives with the ongoing stability and integrity of the network.

1.1.6. Smart Contracts

Smart contracts represent self-executing agreements where the stipulations of a deal are translated into programmable form and hosted on a decentralized blockchain platform.

They deliver a multitude of advantages such as robust **security**, complete **transparency**, tamper-resistant **immutability**, and the **elimination of** the need for **middlemen** like banks or legal representatives. Consequently, smart contracts facilitate smooth and automated transaction processing and asset transfers, minimizing the risk of human mistakes. They possess a broad array of potential applications in various domains, from financial sectors to supply chain management, promising to enhance industrial efficacy, safety, and speed.

Three essential components must be weighed when setting up a smart contract:

1 **Choice of a Stateful Blockchain Platform**: The blockchain platform that supports the execution of smart contracts must be selected thoughtfully.

2 **Programming Language Selection**: Attention must be given to the choice of programming language, as different platforms extend varying degrees of support, and mastering a novel language might pose a significant hurdle.

3 **Consideration of Framework for Testing and Deployment**: The framework used to test and launch the smart contract should be carefully considered since not all of them back the entire array of available programming languages or blockchain networks.

Outlined below are **the 6 most prevalent programming languages** utilized in crafting smart contracts, alongside the blockchain networks they support [15]:

1 **Solidity** (Supported by Ethereum and other EVM-compatible chains)

2 **Rust** (Compatible with Solana, Polkadot, etc.)

3 **Vyper** (Supports Ethereum and other EVM-compatible chains)

4 **Yul and Yul+** (Intermediate languages used within the Solidity compiler)

5 **JavaScript** (through NodeJS) (Functions with Hyperledger Fabric, NEAR)

6 **C++** (Utilized in EOS)

Following these programming languages, here are the **4 top smart contract development settings (frameworks)** [16]:

1. **Hardhat**: A JavaScript-centric development and examination framework for constructing and evaluating smart contracts on the Ethereum blockchain. It furnishes a thorough and tailorable environment for developers to scrutinize and launch their smart contracts on a simulated network, curbing the likelihood of glitches and defects in the live setting.

2. **Truffle:** A favored framework for fashioning and deploying decentralized applications (DApps) and smart contracts on Ethereum. It encompasses a suite of tools for generating and governing smart contracts and a development setting for constructing and assessing DApps. Truffle provides a flexible, comprehensible, and user-centric platform, supporting multiple languages, including Solidity for Ethereum-based smart contract writing.

3. **Brownie**: A Python-oriented development framework for the creation and testing of smart contracts on Ethereum. It includes tools and abstractions to aid developers in effortlessly writing, deploying, and interfacing with smart contracts. Features like contract testing, deployment administration, and web3.py integration for Ethereum node interaction are included. Its user-friendly design aims to simplify the development process, rendering smart contract creation more reachable to a diverse audience.

4. **Embark**: A framework designed for the development of decentralized applications (DApps) on the Ethereum blockchain. It offers a collection of tools and services, enabling effortless DApp building and deployment. Embark includes various features such as a local development setting, smart contract template libraries, and support for diverse development tools and libraries. It also integrates smoothly with well-known blockchain browsers and block explorers, streamlining the interaction with DApps during development and examination.

1.1.7. Decentralized Applications (DApps)

In the following section, we explore the world of decentralized applications, or DApps, for short. Ethereum, from its inception, has been driven to transform the web landscape and herald a novel epoch of DApps, often termed as web3. Whereas smart contracts primarily focus on decentralizing transaction control logic and financial processes, web3 DApps extend this decentralization concept by including aspects such as data storage, communication, and state management.

DApps offer a broader perspective compared to mere smart contracts. In its simplest form, a DApp consists of a smart contract coupled with a web-oriented graphical user interface (GUI). However, when viewed more holistically, a DApp can be defined as a web application built upon open, decentralized, and peer-to-peer infrastructure services [17].

At a fundamental level, a DApp includes the integration of:

- Smart contracts operating within a blockchain framework
- A GUI that's accessible through a web interface

Moreover, many DApps also weave in additional decentralized components, such as protocols for:

- Peer-to-peer decentralized messaging
- Peer-to-peer decentralized storage

These constituents blend to create a DApp that goes beyond mere transactional functionalities, forming a multifaceted system that leverages decentralization to offer a robust and self-sustaining application. By combining these elements, DApps pave the way for a new paradigm in application development, emphasizing transparency, autonomy, and community-driven governance.

1.1.7.1. Advantages over centralized applications

The deployment of a DApp in comparison to a traditional centralized architecture brings forth several unique benefits that cannot be achieved through the latter [17]:

1 **Resiliency**: Since the business logic is overseen by a smart contract, a DApp's backend is fully distributed and governed on a blockchain platform. In contrast to an application hosted on a centralized server, a DApp experiences no downtime and remains continuously accessible as long as the underlying platform is operational.

2 **Transparency:** The on-chain structure of a DApp grants the ability to scrutinize the code and provides greater certainty regarding its functionality.

3 **Censorship resistance:** Provided a user can access an Ethereum node (or run one if necessary), they can interact with a DApp unimpeded by any form of centralized control. Neither service providers nor even the owners of the smart contract can modify the code once it has been deployed on the network. This ensures a level of autonomy and freedom that's unprecedented in traditional systems.

1.1.7.2. Popular DApp Services

Blockchain technology is often tied with cryptocurrencies, yet it harbors a myriad of possibilities extending beyond this sector, encompassing even the realm of physical money or fiat currency. Deriving from the Latin word "fiat," which translates to "let it be done," fiat currency opens new horizons in this context. The following encapsulates some dominant services facilitated by DApps [18]:

- **Money Transfer**: By removing middlemen, the process of sending money from person to person becomes more economical and swifter. This efficiency shines in international transactions, allowing people, for instance, in the USA to send money to the Dominican Republic in mere moments.

- **Lending**: Smart contracts can be transformational in managing secured loans, enhancing processing speed, and slashing costs through automated payment and fund release functions. Lenders, in turn, can provide more appealing interest rates.

- **Insurance**: The insurance sector has often struggled with obscurity, causing client confusion and unseen risks. Smart contracts introduce a transparent relationship between insurers and insured, preventing double claims and ensuring quick payout.

- **Financial Trading**: Decentralized cryptocurrency exchanges are now being provided by various entities, not just individuals, giving them more control and assurance of transaction safety.

- **Real Estate**: The exhaustive paperwork involved in property transactions can be significantly trimmed down through blockchain, while maintaining security and speeding up the process.

- **Personal Information Storage**: With the risk of online security breaches, using a blockchain as a public ledger offers a more fortified platform, minimizing the chance of successful hacking.

- **Data Storage**: The efficiency in distributing state benefits could be markedly improved by keeping identification data on a blockchain.

- **State Storage**: Storing ID information via blockchain could assist in the prompt distribution of government benefits like Medicare, reducing fraud and cutting down costs, thus delivering benefits more swiftly to those qualified.

- **Medical Records Storage**: Storing medical records on blockchain can enhance healthcare by providing accurate patient information, preventing misdiagnoses and incorrect treatments.

- **Voting Functionality**: Enshrining personal identification in blockchain could simplify voting, with its secure and unchangeable nature, encouraging more voter turnout.

- **NFTs**: Using Non-fungible Tokens (NFTs) enables ownership rights over digitally preserved data, especially in digital art. Linking NFTs to blockchain assures the uniqueness of an art piece, easing investment and storage concerns.

- **Royalties**: Maintaining a complete online catalog of musical and film works would reduce copyright violations and ensure timely royalty payment to creators.

- **Logistics & Supply Chain Tracking**: Employing blockchain to track goods in a supply chain can substantially bolster collaboration in logistics, allowing secure access to vital data and enhancing coordination.

- **Security Enhancement for IoT**: The Internet of Things (IoT) gains from the decentralized security offered by blockchain, protecting login information and reducing susceptibility to unauthorized access.

- **Gambling**: For gambling enthusiasts, a blockchain-based casino provides more transparent operations. Every game's result would be permanently recorded, giving players assurance of fairness and privacy.

By touching on various aspects of everyday life, from healthcare to recreation, the applications of blockchain technology demonstrate its immense potential and versatility, promising a future with more transparency, efficiency, and security.

1.2. Blockchain Games (BCG)

The sphere of digital gaming serves as a powerful platform to illustrate the significance of blockchain technology. Seamlessly integrated within the virtual currency landscape, and devoid of the common data entry woes found in other Decentralized Applications (DApps), it fulfills the desires of numerous gamers. Blockchain technology represents the ideal vision for players, facilitating the possession of unique, inheritable, and self-sufficient virtual items within the gaming environment, free from the restrictions levied by the game service provider. In a study carried out by Tian Min et al. [19] in 2019 concerning blockchain-enabled games, a clear and authoritative definition of blockchain games (BCG) emerged. These were described as a category of digital games conceived and operated on the basis of blockchain technology's core principles.

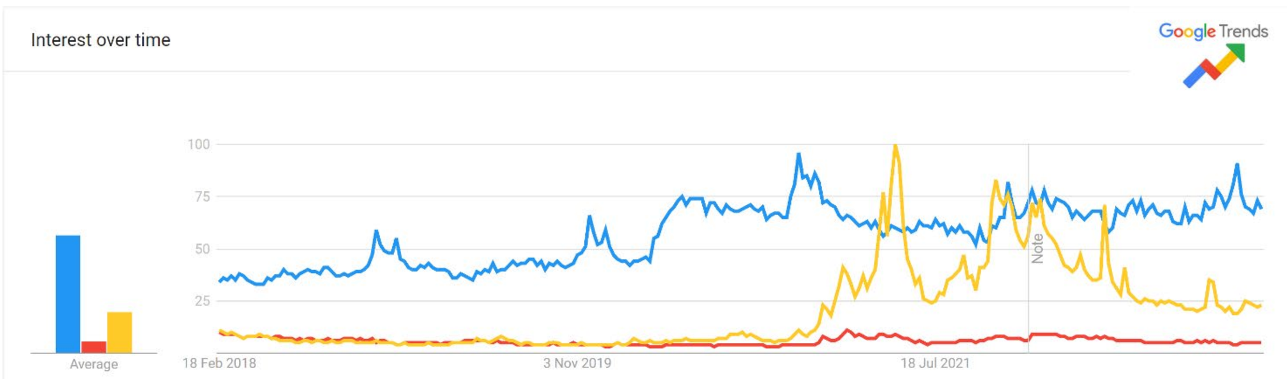

Figure 4*: The correlation between: Gaming (Blue), Crypto (Yellow) and Blockchain (Red) by Google Trends. Obtained: (23 April 2023).*

1.2.1. Benefits of BCGs

Rule Transparency: With blockchain technology's inception, the gaming world has reaped various beneficial effects. Among these is the enhancement of transparency concerning game rules. The unchangeable and transparent nature of blockchain data affords players or third-party entities the ability to scrutinize the foundational rules of games based on smart contracts, a facet often hidden in conventional, centralized gaming mechanisms. This elevated transparency reinforces the overall integrity and trustworthiness of gaming practices.

Asset Ownership: Traditional digital gaming platforms maintain control over virtual commodities such as credits, items, and avatars since this information resides on their servers. The advent of blockchain empowers players with total ownership of their gaming assets, as they are tethered to their distinctive addresses. This not only grants players full autonomy over their virtual belongings but also ensures that these assets retain value and applicability beyond the control of specific game operators, preserving players' investments and in-game relationships even if the game ceases to exist.

Assets Reusability: Blockchain inherently serves as an open repository containing both data and executable instructions. This permits game creators to tap into its potential, constructing a gaming ecosystem where players can repurpose their in-game characters and assets across various games. Such interoperability supports new game launches, allowing them to instantly utilize the existing assets from preceding games.

User-Generated Content (UGC): In conventional gaming landscapes, users' content creation is restricted to a specific game, effectively granting ownership to the game operator. The advent of blockchain transforms this dynamic, enabling players to retain control over their UGC and potentially share it across diverse games. This novel approach encourages players to actively contribute new content, cultivating an energetic and flourishing gaming community.

In summary, these benefits signal the gaming industry's progression towards integrating blockchain technology into its core functions. The establishment of the Blockchain Game Alliance in September 2018 underlines the sector's concerted efforts to delve into and capitalize on blockchain's potential within video gaming. However, the academic world still needs to thoroughly investigate and comprehend the profound impact this technology may wield on the future contours of the gaming industry [19].

1.2.2. Serious Blockchain Games (SBCG)

1.2.2.1. Serious Games (SG)

Serious games represent a specialized category within the gaming industry, distinguished by goals that extend beyond mere amusement and recreation [20]. These games are tailored to fulfill a more substantial function, such as instruction, promotion, emulation, and schooling [21]. Engaging with serious games encourages players to reflect and make choices that are both mentally engaging and provide meaningful insights. Prominent instances of serious games encompass simulations related to the choice of cargo transport methods [22], scenarios involving hostage rescue [23], and challenges connected with yard crane scheduling [24].

Numerous businesses and organizations commonly resort to utilizing serious games for the training of their employees, covering the conveyance of systemic understanding to the users. This involves various tasks, ranging from instructing on how to assign customers to dining tables [25], acquainting individuals with the procedures and hurdles of maintaining train tracks [26], to teaching statistical concepts [27].

1.2.2.2. Integrating Blockchain into SG

The integration of blockchain technology with serious games unveils a spectrum of intriguing benefits in contrast to traditional backend systems. By decentralizing the backend systems through blockchain, there's a reduction in the game developers' necessity to incessantly oversee centralized servers, given that the blockchain acts as a self-reliant network and manages the essential data of the game.

Moreover, the incorporation of blockchain technology facilitates a smoother development of key components of serious games, such as in-game currency, trading, and integrity of assets. The intrinsic peer-to-peer network architecture also yields enhanced performance within serious games. Most notably, the employment of blockchain allows for effortless authentication of a player's engagement and fulfillment of a serious game. Through the use of smart contracts, game designers can issue and transfer a unique, non-exchangeable token (NFT) to a player's wallet address in reaction to particular activities carried out within the game (e.g., successful completion of all game scenarios). Consequently, third parties can straightforwardly confirm the player's triumphant completion of the task.

Numerous Serious Blockchain Games (SBCGs) have been constructed by the academic community, aiming to investigate an array of different aspects. Below are three examples of such SBCGs:

1 *Yustus Eko Oktian et al.* [28] fashioned a serious game to assist in learning about blockchain mining. The game is designed with an engaging narrative that motivates players to partake in mining-centric activities.

2 *Yunifa Miftachul Arif et al.* [29] endeavored to design a SBCG concerning the enhancement of tourists' destination selection, employing the inherent features of blockchain for handling transactions. The authors concentrated their study primarily on the characteristics of the

transactions, and through various evaluations, their findings suggest methods to ameliorate these transaction attributes by altering factors such as gas price and gas limit.

3 *CEBT (Cybersecurity Enhancement through Blockchain Training)* [30] is an SBCG created by Ansh Mittal et al., aimed at enlightening the broader public about the technology. Their objective is to stimulate extensive acceptance of this cutting-edge solution, with the intention of substantially augmenting the security within the information systems field.

1.2.3. BCG Architecture

Blockchain games, also known as web3 games, are composed of multiple components, each fulfilling a critical role in delivering the gaming experience. The architecture typically consists of the game client, game server, and the blockchain [19] as illustrated in **Figure 5**.

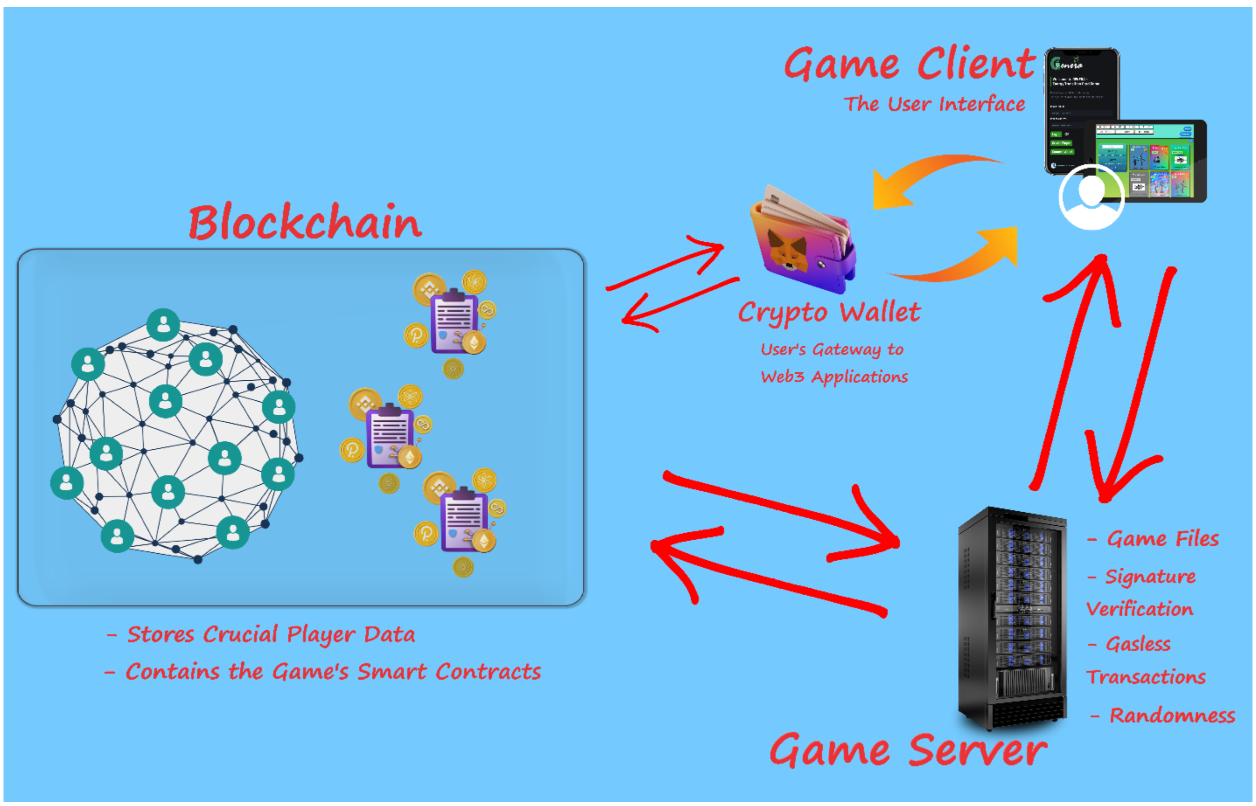

Figure 5*: The Architectural Framework of a BCG. Adapted from [19].*

Frontend Component: The game client, otherwise known as the User Interface (UI), serves as the player's gateway to the game. It acts as a bridge, communicating with both the blockchain and the game server. Crafting a user-friendly and intuitive UI is an intricate task in the realm of blockchain games, largely due to the convoluted nature of blockchain dealings and wallet operations. To mitigate this, developers must simplify the majority of the blockchain's complexities within the UI, thus presenting an experience reminiscent of conventional online games.

Backend (Game Server): In the standard gaming environment, a web server controls aspects like game logic, player information, session oversight, and instantaneous updates. In the domain of blockchain gaming, this server also liaises with the blockchain, dispatching transactions and fetching data. In contrast to conventional games, not every piece of game data is housed on the server. Only essential details necessary for carrying out game logic, or non-critical data, are kept within this section. This can encompass files tied to visual facets of the game, such as images and 3D designs, or real-time aspects like the coordinates of player characters.

Blockchain: This decentralized network serves as the repository for vital game assets, player stats, and other indispensable information, such as records of ownership for in-game items, player achievements, or in-game currency. The unalterable quality of blockchain guarantees the veracity and genuineness of this data. Nevertheless, the blockchain backend faces challenges, such as scalability. The surge in transactions and the obligation to store ample game data may result in delays and sluggish transactions. To address this issue, layer 2 [31] solutions like Polygon [32] and Arbitrum [33] can be deployed for executing off-chain transactions, thus alleviating the burden on the primary blockchain. Layer 2 in blockchain refers to an auxiliary protocol or technology positioned over an existing blockchain infrastructure, principally aimed at boosting transaction pace and scalability.

1.2.4. Tokenization: The representation of assets through NFTs

The emergence of blockchain technology has opened a myriad of possibilities for game creators, financiers, and digital artists via token creation [34]. The meteoric rise in popularity of Non-Fungible Tokens (NFTs) for the transaction of virtual assets is showcased through high-profile sales, including those of digital artwork worth millions, as highlighted by reputable sources like The New York Times [35]. This has ignited extensive curiosity in employing blockchain for trading digital commodities.

1.2.4.1. Tokens and Token Standards

The historical context of tokens as a transactional medium dates back to their use as a currency for acquiring goods and services, a custom still prevalent today in varied domains like casinos, arcade games, public transit, and shopping cart rentals.

With the innovation of digital tokens anchored in blockchain technology, an expansive array of opportunities has emerged alongside significant hurdles for those involved in the artistic and gaming spheres.

Three leading token standards within the blockchain environment stem from Ethereum Request for Comment (ERC) proposals. These standards delineate specific regulations and functions to be adhered to by Ethereum-based tokens, guaranteeing compatibility and coordination with other protocols on the platform. Three ERCs stand out prominently:

- **ERC-20 [36]** serves as a digital representation of various assets like virtual currency, property rights, shares, or other fiscal instruments. These tokens can be purchased, traded, or exchanged on digital currency platforms or via direct peer-to-peer dealings. ERC-20's popularity has solidified its position as a common standard for the issuance and trading of digital commodities.

- **ERC-721 [37]** introduces a non-fungible token (NFT) standard for Ethereum and similar blockchains. Unlike its fungible ERC-20 counterparts, ERC-721 tokens are unique and characterized by distinct attributes. These tokens are suited for symbolizing rare and exclusive digital possessions like art, collectibles, virtual properties, and in-game elements. ERC-721 has gained traction for enabling decentralized acquisition and trading of these assets without middlemen.

- **ERC-1155 [37]** expands on ERC-20 and ERC-721, offering a comprehensive interface for both fungible and non-fungible tokens within a singular contract. This standard facilitates the crafting of tokens with uniform or distinct values within one agreement, affording higher versatility and more economical resource utilization on Ethereum and analogous blockchains. ERC-1155 has found applications in tokenizing gaming objects, collectibles, and other singular virtual assets.

1.2.4.2. Tokenization in Games

The importance of digital asset ownership in the gaming landscape and related sectors is on an upward trajectory. This pattern is corroborated by research from Livingstone et al. [38], who underscore that digital items can possess diverse significance for gamers, including but not limited to utility, investment, social interaction, reminiscence, pleasure, symbolic of relationships, novelty, artistic expression, companionship, and individuality.

The deployment of rewards within games has been empirically demonstrated to effectively stimulate players [39] [40]. Both intrinsic and extrinsic incentives have been observed to foster prolonged engagement with a game and inspire return visits [39] [41]. The argument by Scholten et al. [42] that cryptocurrencies on platforms like the Ethereum blockchain could enhance player commitment to gaming further supports this concept.

Komiya and Nakajima [43] have put forward a blockchain-oriented approach to spur players through accomplishments. These applications encompass the acquisition and allocation of scarce in-game assets, collectible items, user-designed creations, gifts, and autographed objects from esports athletes or live-streamers. This proposal aims to explore and articulate pertinent applications for tokenization, characterized as the utilization of NFTs to symbolize digital valuables, with a specific focus on the game development industry.

1.2.4.3. Collectibles and Crypto-assets

The practice of collecting tangible objects for pleasure, driven by nostalgia, an affinity to a specific period or historical moment, status, or economic gain, is far from a contemporary phenomenon [44]. While the collection of digital assets has been a pursuit for some over time, the emergence of NFTs (Non-Fungible Tokens) has facilitated the accumulation and trade of these virtual items.

Within the sphere of Massively Multiplayer Online Role-Playing Games (MMORPG), players gather in-game assets through playing, accomplishing quests, or buying from either the in-game store or external sources [45] [46]. This setup creates opportunities for individuals in countries like China and Mexico, characterized by better internet connectivity and lower living costs, to engage in these games as full-time occupations and monetize the resulting in-game assets on commercial exchange platforms such as eBay [46].

Despite the determined efforts by game developers to curb these transactions through measures that obstruct them, the act of collecting and selling in-game resources, commonly referred to as "gold farming," continues to endure [47]. For game developers, there are promising prospects, such as the integration of unique rewards for players or teams, in-game artistic creations, or tradable collectibles.

1.2.5. Popular Platforms for BCGs

The critical importance of the consensus protocol utilized in a blockchain, as emphasized in subsection 1.1.5, is essential. These protocols govern the manner in which nodes converse and reach consensus, and also verify transactions. It's worth noting that specific consensus models, such as DPoS and PoH **[48]** (Proof-of-History, employed in Solana), deliver rapid transaction speeds, while others like PoW favor security. Considering the urgent demand for substantial TPS (transactions per second) and quick response times in Blockchain Gaming (BCG), consensus mechanisms like DPoS and PoH are often seen as more appealing compared to PoW. As a result, the following five modern blockchain networks, known for their emphasis on speed, are commonly recognized as top choices in the gaming sphere:

- **TRON [49]** is a decentralized platform that facilitates the crafting and implementation of smart contracts and decentralized applications (DApps). It stands out for its goal to offer high scalability and support for high-throughput activities, making it fitting for applications within the entertainment and gaming sectors.

- **NEO [50]**, a blockchain platform that backs the creation and execution of smart contracts and decentralized applications, is unique in its compatibility with various programming languages like C#, Java, and Kotlin. This accessibility allows developers with existing knowledge to construct on the platform more effortlessly. Additionally, NEO utilizes a delegated Byzantine Fault Tolerance consensus method, aiming for a more energy-conserving alternative to proof-of-work.

- **Qtum [51]**, an independent network that amalgamates the reliability of the Bitcoin blockchain with Ethereum's smart contract functionalities, distinguishes itself by utilizing a mixed consensus model combining proof-of-stake with proof-of-work, thus capitalizing on the advantages of both systems.

- **Nebulas [52]**, a blockchain platform that offers a search engine and incentivizes developers to produce top-quality decentralized applications, is singular in its application of a custom ranking algorithm known as the Nebulas Rank (NR). This algorithm assesses the value of decentralized applications and rewards developers for high-quality contributions.

- **EOS [53]** is a decentralized platform specialized in the creation of DApps, is noted for its robust performance and scalability. What sets EOS apart is its use of a delegated proof-of-stake (DPoS) consensus process, wherein token owners cast votes for block producers, who in turn authenticate transactions and append blocks to the chain.

Section 2: Methodology

This section furnishes a comprehensive study of a blockchain-powered serious game called *"Genera Web3 Game"*. The SBCG's custom blockchain network, development, employed technologies and technical implementations shall be described and analyzed.

The game forms an integral part of the **GENERA project**, which endeavors to advance energy transition strategies within municipalities and boost the usage of monitoring tools dedicated to energy transition. **The game design** ensures an engaging Dapp experience, necessitating the establishment and operation of a cryptocurrency wallet for game access. Players can transfer in-game gold tokens using their crypto wallets and trade their virtual assets through the game's **Marketplace** by creating and signing transactions. A **Leaderboard** is also developed which goal is to boost player engagement, retention and insert a sense of competitiveness.

The **GENERA platform** features two additional Dapps, a Rewarding Tool and a Social Forum. The **Rewarding Tool** Dapp offers users the opportunity to earn *MyGreenScore (MGS) tokens* by interacting with various platform web features, such as the Genera Web3 Game and the Social Forum. Users can redeem these tokens for diverse rewards, the kind of which depends on the project's contributing partners.

The **Social Forum** is a web-enabled platform designed to enhance its registered members' ability to participate in discussions centered around the project. It serves as a vibrant, cooperative center where members can express their thoughts on a range of topics. It can be accessed without the need of a crypto wallet, however, in that case the rewards (in the form MGS Tokens) will be lost.

The developed game utilizes a **private custom-made Blockchain network**, which, while being an offshoot of the Ethereum network, it employs Proof of Authority (PoA) [54] for its **consensus algorithm**. This network oversees crucial activities, including the exchange of in-game and MyGreenScore (MGS) tokens by users, the trading of Non-Fungible Tokens (NFTs) within the Social Serious Game Marketplace, and tracking the earning and spending of MGS tokens by users for rewards. The network's structure includes two Ethereum miner nodes and one bootnode, each functioning on an exclusive Virtual Machine (VM).

The game's operational performance and player experience is enhanced by the Express.js framework and a MySQL database. These tools process data that is not fundamentally critical, yet essential for various functions like facilitating gasless transactions [55] and validating a user's digital signature, eliminating the need for personal data.

2.1. Custom Blockchain Network

The developed platform (GENERA) leverages a blockchain network to facilitate various critical operations:

- Users' ability to **exchange** their **in-game** tokens **and MyGreenScore** (MGS) **tokens**.
- **NFT sales** within the SBCG's Marketplace.
- Monitoring the accumulation and expenditure of MGS tokens by users in exchange for rewards.

To perform these crucial functions, a private Blockchain network, based on the Ethereum network [56] but utilizing Proof of Authority (PoA) [54] as the consensus mechanism, has been established. It incorporates two Ethereum miner nodes and one bootnode. These nodes are interconnected, forming a distributed network of trust, with the bootnode assisting new entries in joining the network.

Each miner operates on a dedicated Virtual Machine (VM), and they exchange packets located at the top of the shared ledger. Synchronization across all nodes is achieved via a shared genesis file.

The following sub-sections will delve into the technical implementation of the network.

2.1.1. GETH

Geth (go-Ethereum), a widely-used Ethereum execution client developed in Go language, handles transactions, deploys and executes Smart Contracts, and houses the Ethereum Virtual Machine (EVM) [57].

In Ethereum, data is distributed directly between nodes following certain rules that enable the network to agree on its present state. Every 12 seconds, a node is randomly selected to generate a new block, listing transactions for other nodes to validate and execute. These individual blocks are connected using robust encryption, forming a blockchain. Geth uses the information contained in each block to update its state – the ether balance of all Ethereum accounts and the data stored by each smart contract [58].

There are **two kinds of accounts in Ethereum** [59]:

- Externally-owned accounts (EOAs)
- Contract accounts.

Contract accounts execute code when they receive transactions with Data field information. In contrast, EOAs are used by users to sign and send transactions. Each EOA corresponds to a public-private key pair, with the public key used to generate a unique user address and the private key used to secure the account and sign messages securely.

Thus, to use Ethereum, it's first required to generate an EOA (henceforth, "account"). Running Geth along with a consensus client transforms a computer into an Ethereum node.

2.1.2. Consensus Algorithm Selection

The term consensus, in a distributed setting, pertains to the protocols enabling a network of nodes to agree on the state of the blockchain ledger.

As of September 2022, Ethereum uses a Proof-of-Stake (PoS)-based consensus mechanism. This mechanism secures the network using a system of rewards and penalties applied to capital locked by selected users participating in the consensus mechanism. These users (Validators or Stakers) are responsible for proposing the next block. This incentive structure promotes honest behavior among Validators and penalizes dishonesty, thereby safeguarding the network.

There's also a process governing how honest validators are chosen to propose or validate blocks, process transactions, and vote for their version of the chain head. In rare instances when multiple blocks contest for the same position near the head of the chain, a fork-choice mechanism selects blocks that form the 'heaviest' chain, determined by the number of validators voting for the blocks, weighted by their staked ether balance. These elements collectively form the consensus mechanism.

While the main network employs Proof-of-Stake (PoS) to protect the blockchain, Geth also offers 'Clique' Proof-of-Authority (PoA) consensus algorithm and the Ethash Proof-of-Work (PoW) algorithm as alternatives for private networks. Clique is often recommended for private networks as **PoA consumes far fewer resources than PoW**.

The 'Clique' consensus algorithm is a PoA system where new blocks can be created by authorized 'signers' only. <u>The original set of authorized signers is configured in the genesis block</u>. In the case of GENERA's network, the initial count is two miners. Signers can be authorized and de-authorized using a voting mechanism, allowing the set of signers to evolve as the blockchain operates.

Clique can be tailored to target any block time (30 seconds in GENERA blockchain) since it's not linked to the difficulty adjustment that other consensus algorithms use (e.g., the PoW consensus).

2.1.3. GENERA's Blockchain GENESIS Block

Every blockchain originates with a genesis block [60]. When Geth is run with default settings for the first time, it commits the MainNet genesis to the database. For a private network like GENERA, a distinct genesis block is generated.

The genesis block is configured using a **genesis.json file**, which must be supplied to Geth at start-up. When creating a genesis block, a few preliminary parameters for the private blockchain must be set, like:

- **Initial block gas limit** (gasLimit): This determines the maximum EVM computation that can occur within a single block.

- **Initial allocation of ether**: This sets the amount of ether accessible to the addresses listed in the genesis block. Additional ether cannot be created through mining in the GENERA network.

```
PS C:\Users\Jimzord12\Documents\Programming\Ethers_Scripts> node script.js
Genesis Block: Block {
  provider: JsonRpcProvider {},
  number: 0,
  hash: '0x11113c0865a34b3428f37b5fff316bce337bf53b0c8899fd73883b556870449e',
  timestamp: 0,
  parentHash: '0x0000000000000000000000000000000000000000000000000000000000000000',
  nonce: '0x0000000000000000',
  difficulty: 1n,
  gasLimit: 800000000n,
  gasUsed: 0n,
  miner: '0x0000000000000000000000000000000000000000',
  extraData: '0x00000000000000000000000000000000000000000000000000000000000000009f1873938383a259b921133e8fce6
fec60361ee97335cdee92bf6341e9e18bcdd087d279b8520aed00000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000000000000',
  baseFeePerGas: null
}
```

Provider's RPC URL

***Figure 6**: Genera's PoA Network genesis file.*

2.1.4. Bootnode

When a new node joins an Ethereum (or Ethereum-based) network, it needs to connect to existing nodes to discover new peers and synchronize ledger data.

These entry points into an Ethereum network are referred to as bootnodes. The GENERA network operates a bootnode to provide this functionality, facilitating future network scalability as required.

2.2. The Serious Blockchain Game (SBCG)

During the creation of this SBCG, we adopted an innovative approach. This diverges from the commonly used methods by scholars referenced in the subsection 1.2.2.2, who typically leveraged the Unity Game engine for graphics and housed their smart contracts on established blockchain networks.

In this project, the game is presented in a 2D format, accessible via browsers and supports multiplayer gameplay, promoting greater accessibility and encouraging player engagement. Furthermore, rather than using an existing blockchain network, we rolled out our bespoke blockchain platform for the game's smart contracts. A **unique feature** of the game is its **immersive Dapp experience**, as it requires players to establish, fine-tune, and operate a cryptocurrency wallet to access the game. Players also have the option to transfer in-game gold tokens using their crypto wallets.

The particular game seeks to introduce a series of energy transition tactics in municipalities, steering them from initial planning to the realization of initiatives and public participation in tourist islands, in alignment with the Covenant of Mayors. Secondly, it promotes the use of energy transition monitoring tools, aiding in tracking their advancement.

In line with GENERA's objectives, the game is designed to captivate users while enlightening them on the importance of adopting innovative energy alternatives. This encompasses urgent energy challenges, such as reliance on fossil fuels, soaring electricity costs, and the associated environmental impacts.

2.2.1. Employed Technologies

When creating the **frontend component**, as outlined in section 1.2.3, we harnessed React [61], a renowned web development library by Meta (previously known as Facebook). This library stands out for its prowess in shaping detailed and dynamic user interfaces for web-based applications. Thanks to React, the game runs smoothly in browser settings, broadening its reach to anyone with a browser-enabled device, while sidelining the need for high-end graphic hardware.

For the **backend**, as detailed again in the same section, the foundation rests on *Node.js* [62], bolstered by the *Express.js* framework [63] and a *MySQL* database [64]. This ensemble was curated to supercharge the game's operational efficiency. Even though some of these technologies handle data that isn't core critical, they remain indispensable for several functions. These include:

- Validating a user's digital signature through the *ethers.js* library [65].
- Supporting gasless transactions [66].
- Introducing randomness via a number generated by *NodeJS's crypto module* [67].

Speaking of gasless or meta-transactions, they allow a third-party to foot the gas bill instead of the original sender. To integrate this feature, *Thirdweb* [68] was incorporated, a cutting-edge web3 development framework. It offers an SDK solution that introduces this function via the *OpenZeppelin Defender* [69] provider.

For the blockchain network, the game rides on GETH [70], a frontrunner among Ethereum's implementations. Interested readers requiring more specific details about the current implementation can visit section 2.1. GETH's robustness, popularity, and exhaustive documentation streamlined our development journey. We anchored our network on GETH's "Clique" [71], a PoA (Proof-of-Authority) consensus protocol. PoA is distinct in that it opts for validators based on their trustworthy identity, achieved through a meticulous selection process [72]. While PoA stands out for its energy thriftiness and rapid transactions, it does have a centralization trade-off. Key features of PoA include:

- A predefined set of validators.
- A non-competitive block creation environment.
- Minimal resource demands.
- Swift transaction finalization.
- Efficient storage and processing.

Moving to the **smart contracts**, as described in subsection 1.1.6, we distilled the logic into three distinct contracts.

Firstly, the **TokenManager** contract shoulders the responsibility of spawning, safeguarding, and shuttling the game tokens. This game adopts two token kinds: in-game gold, which mirrors ERC-20 [73] due to its currency-like nature, and in-game cards, echoing the traits of ERC-721 [74], commonly known as NFT [74]. To navigate both tokens within a unified contract, we opted for the ERC-1155 [74] token blueprint. This model stands out in many blockchain projects due to its efficiency, gas savings, and multifaceted transactional capabilities [74].

Next is the **GameManager** contract, which enshrines all game-related logic from the blockchain's lens. For instance, the 'createPlayer' function is triggered when a new player enters the scene.

Lastly, the **Marketplace contract** holds all logic related to in-game trading.

To breathe life into these contracts, we leveraged **Solidity**, a go-to language for minting smart contracts on Ethereum Virtual Machine (EVM) compatible chains. The entire testing and roll-out phase was streamlined by the **Hardhat** framework, which operates on JavaScript or TypeScript.

2.2.2. Story and Gameplay

The game's story is set in the year 2045, against the picturesque backdrop of the islands in the Mediterranean Sea. Imagining a Europe in the throes of an energy crisis, daily life becomes chaotic. Metropolitan cities grapple with unprecedented power shortages, and even the government struggles to ensure consistent energy supply, especially in the more remote areas.

Stepping into this world, players take on the role of the mayor of a quaint island town in the Mediterranean. Their mission is to alleviate the energy shortages and improve the quality of life for its residents. To do this, they'll need to construct Renewable Energy Generators (REGs) to power essential Buildings - hospitals, dining places, and artisan workshops.

As the mayor, players will also oversee the townspeople, assigning them to various professions. Four primary roles are available: the private sector (which generates gold), concrete collection, metal extraction, and crystal gathering. These materials are crucial for establishing and enhancing both REGs and Buildings.

While REGs provide the much-needed electricity, Buildings have unique benefits. Some Buildings offer passive advantages, such as elevating the standard of living for the island's inhabitants. Others provide active bonuses, like equipping workers with upgraded tools, thereby speeding up resource accumulation. In the game, REGs and Buildings are visualized as cards, as illustrated in **Figure 8**. There's also a category called Special Effect Cards. These are less tangible but powerful; when used, they grant players a 12-hour boost, enhancing specific in-game metrics. For instance, one card might increase the rate of resource collection based on its rarity level.

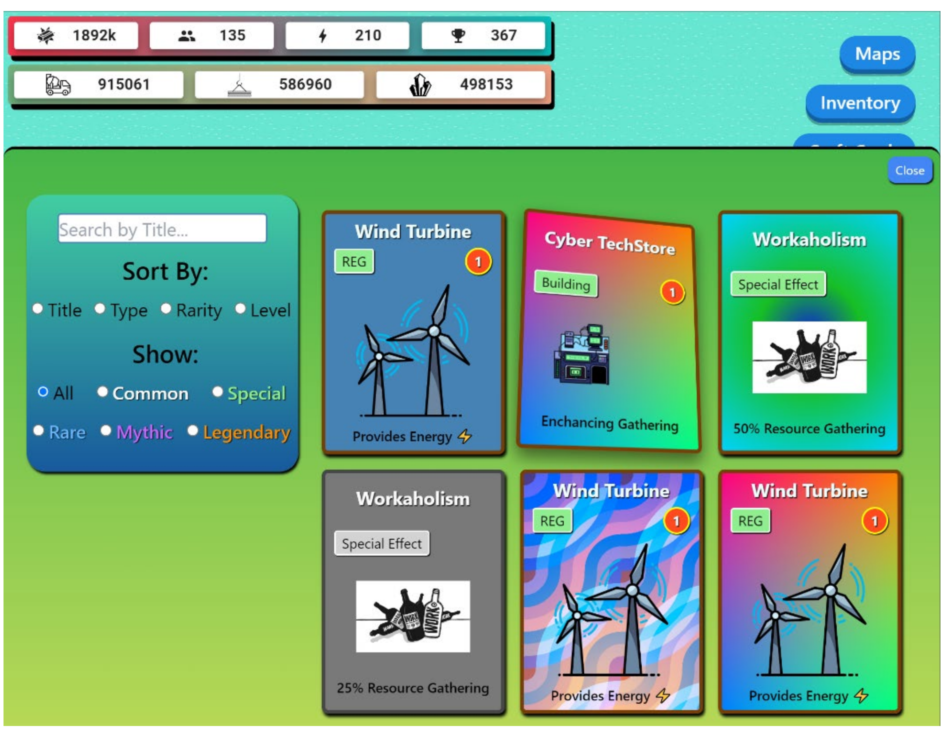

***Figure 7**: The Game's Digital Ownable Assets (NFTs).*

Central to the game is the "Town Hall" building, as showcased in **Figure 9**. This pivotal structure is a constant presence from the game's commencement, and players cannot sell or remove it. Acting as the nerve center of the town, the Town Hall offers players insights into crucial statistics like the number of inhabitants, their growth rate, and the town's energy output (**Figure 10**). It's also the locale where players assign roles to their townsfolk, as detailed in **Figures 11**. When players enhance or "level up" the Town Hall, they unlock the potential for the town's expansion—making room for additional REGs and Buildings, and welcoming more residents to their flourishing town.

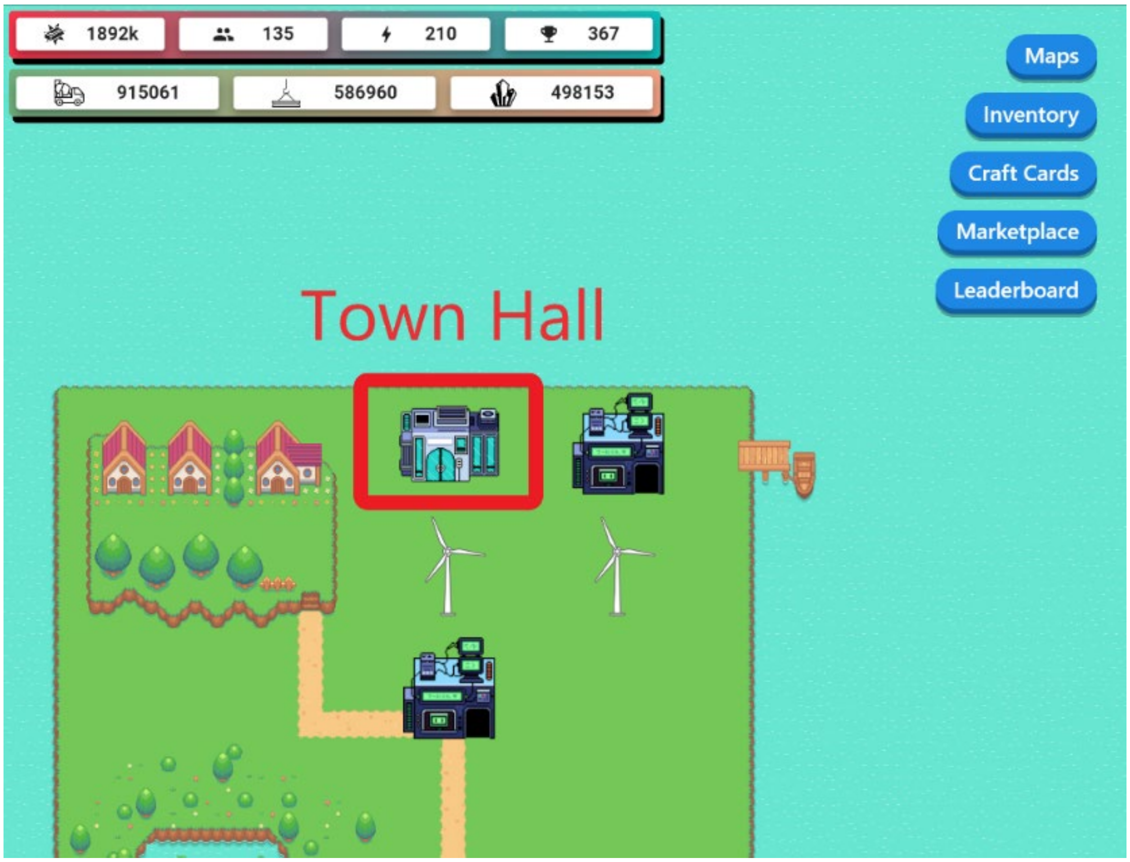

***Figure 8**: The Player's Main Hub of Operations: The Town Map.*

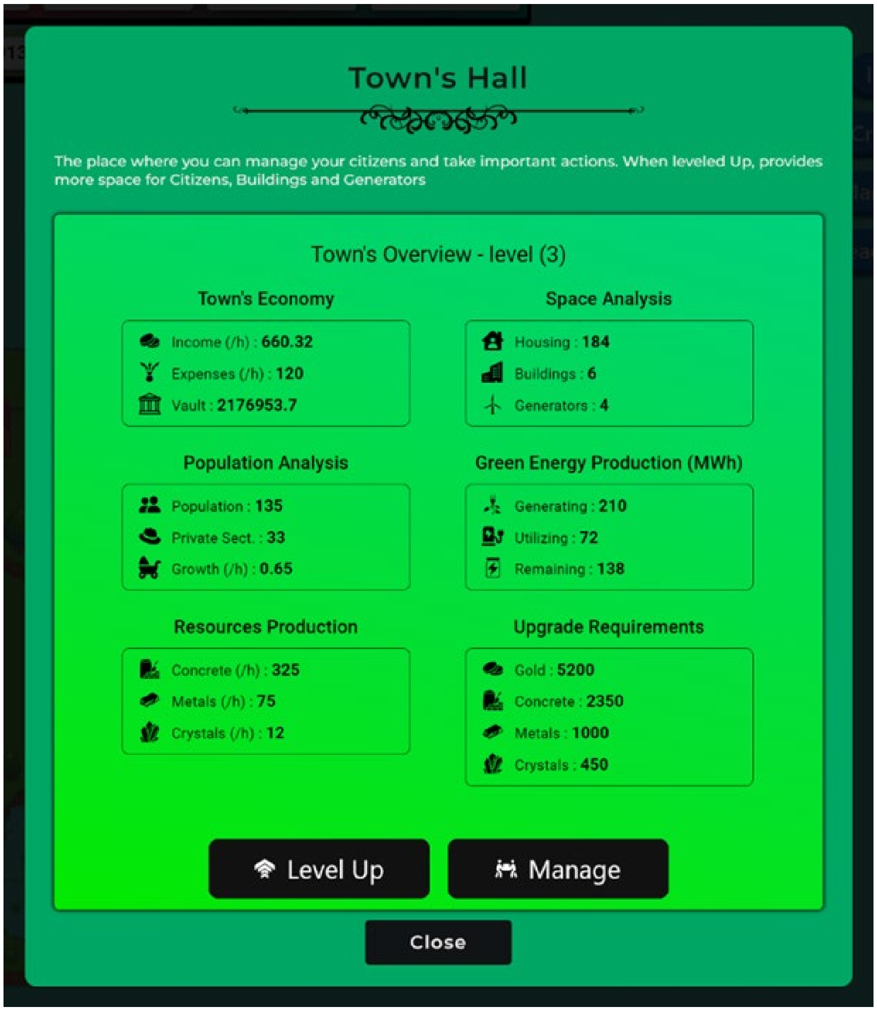

Figure 9*: The Menu of the Town Hall (Starting Building).*

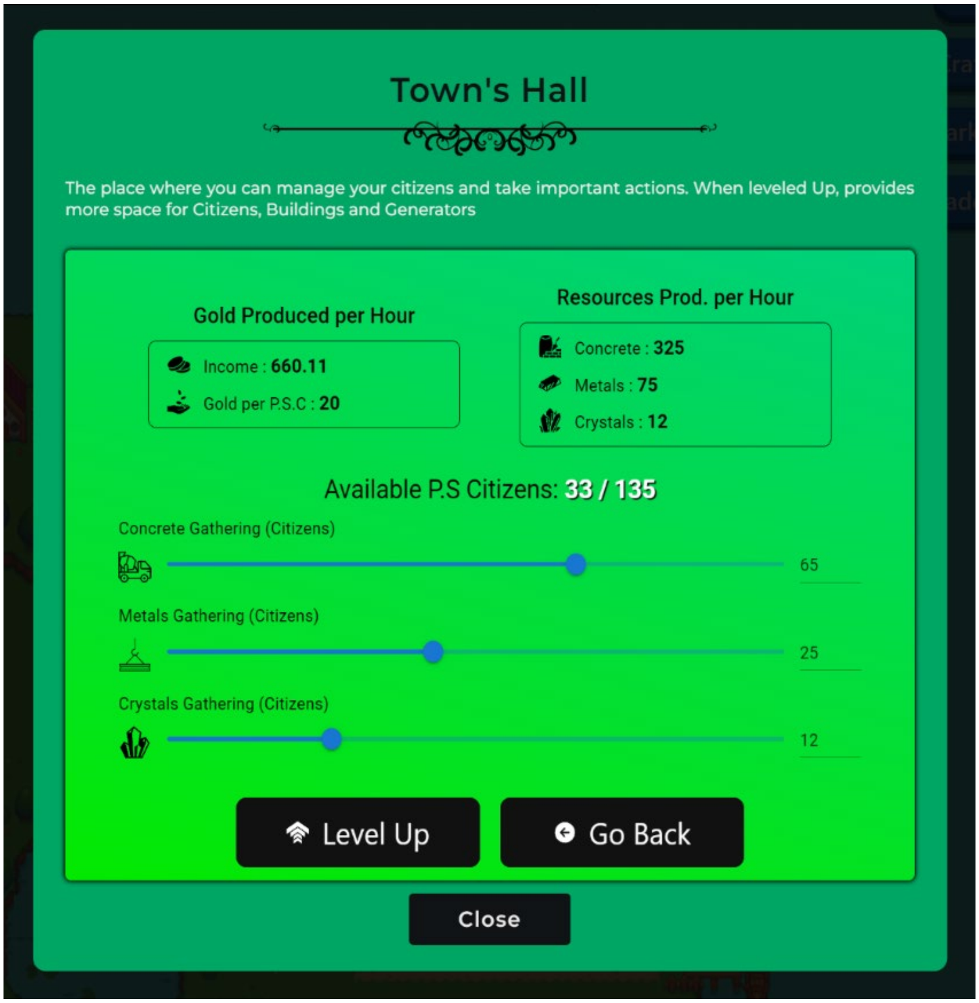

***Figure 10**: The Residents' Occupation Management.*

A crucial gameplay aspect is the living standards score, which reflects the town's population growth trajectory. Notably, as the population burgeons, enhancing the living standards becomes more challenging. Yet, players can leverage specialized Buildings to bolster this score, ensuring consistent and sustainable population increments.

The game embraces the thrill of competition by integrating multiplayer online features, thus heightening player engagement. Players are driven to climb the competitive ranks, as their Ranking Score is contingent on both their town's population size and green energy production. **Figure 12** exhibits the game's leaderboard. Occupying a higher rank on this leaderboard promises more bountiful rewards. Within the game's narrative framework, this is represented as the regional governments recognizing and rewarding the mayor's notable achievements, gifting them with in-game incentives such as gold, essential resources, or cards. The Rewarding Tool Dapp also amplifies this aspect of gameplay, granting the top 100 players with the coveted MyGreenScore (MGS) tokens. The more eminent a player's position on the leaderboard, the more tokens they stand to gain.

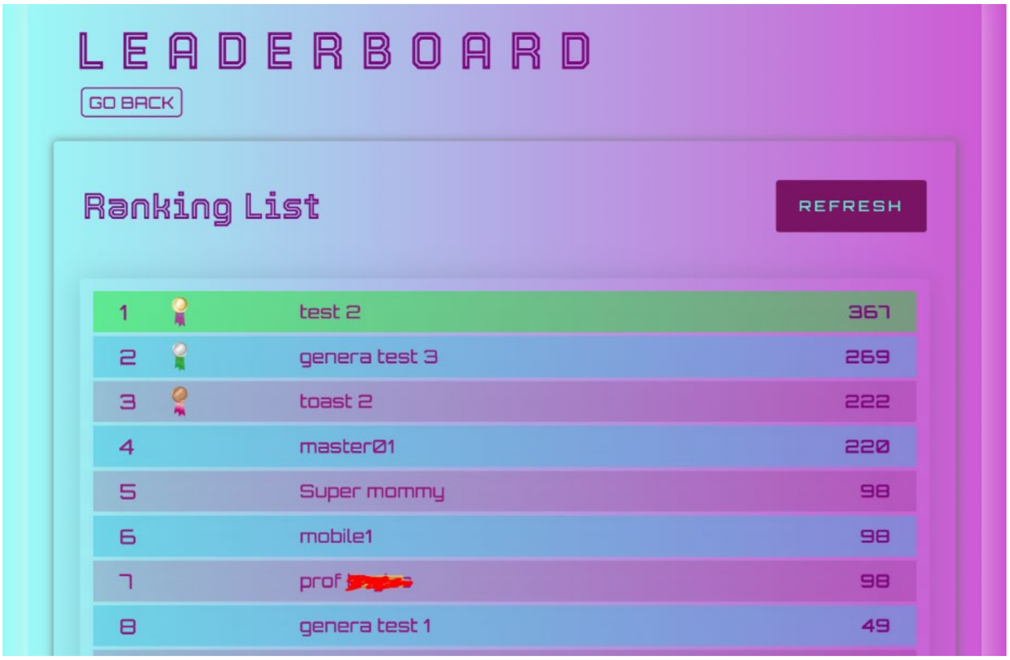

Figure 11*: The Ranking List Page (Leaderboard).*

Finally, the Marketplace (**Figure 13**) introduces an interactive multiplayer dimension, fostering collaboration and trade between players. This space allows gamers to buy and sell cards to one another. Such a feature enriches the gameplay, offering players the chance to craft more sophisticated and creative game plans.

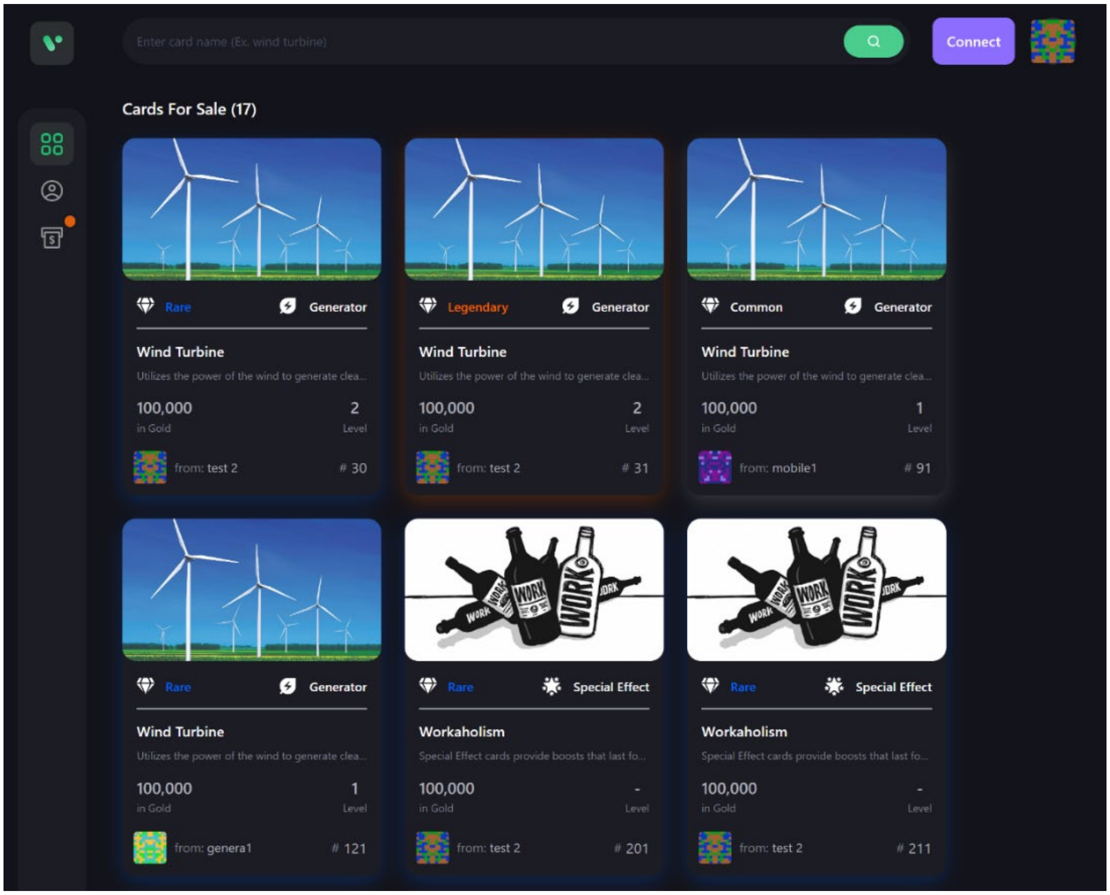

***Figure 12**: The Game's NFT Exchange Point (Marketplace).*

2.2.3. Game Mechanics

In this section, we delve into the intricate mechanisms that are foundational to the application. We'll shed light on these critical components, comprehensively analyzing their operations, their symbiotic relationships, and their contributions to the application's seamless performance.

Starting with the frontend, often termed the User Interface (UI), **the game loop** stands out as the pivotal segment of code. It's the heartbeat of the UI. This continuous loop recalculates and updates the player's metrics every 5 seconds, while also executing safety checks. These refreshed data points are initially retained in the device's local memory and only get transferred to the blockchain after a sixty-second interval. Such an approach acts as a safeguard against potential scalability challenges, considering that more frequent updates would exponentially bloat the network's storage and ratchet up the demand for processing power. The game is architected to ensure that temporary disconnections, lasting a few minutes, won't detrimentally affect the player's trajectory. Moreover, players aren't mandated to have their devices constantly active. With each sync, a timestamp gets etched onto the blockchain. The game loop also harbors a feature termed "catch up", which calculates the time lapse since the player's previous engagement and determines the resources to be credited. This functionality, given its hefty computational demands, is housed within the game client's code. Placing it on the blockchain might spur scalability challenges. Nonetheless, such an approach is commonly viewed with skepticism, as the game client can be a soft target for manipulative attacks.

Next in line is the intriguing mechanism of **user authentication**. Depictions of the login and sign-up interfaces can be found in **Figure 14**. The way decentralized applications (Dapps) handle authentication is a stark departure from traditional methodologies. The conventional duo of usernames and passwords give way to public and private keys. During the authentication phase, the Dapp forwards a message – infused with pertinent text and a randomly spawned number (visible in **Figure 15**) from the game server – to the user's cryptographic wallet. The wallet then prompts the user to peruse and, if agreeable, affix their signature to the message. This autographed message, twinned with the user's public key, is channeled back to the game's server. Leveraging sophisticated cryptographic validations, it's ensured that the true owner of the public key is authenticating, sidelining the need to handle any personal or sensitive data. This modus operandi not only enhances security but also bestows users with the luxury of utilizing a single wallet to interact with myriad Dapps. Essentially, blockchain transfers user agency from the clutches of the application to the individual's domain.

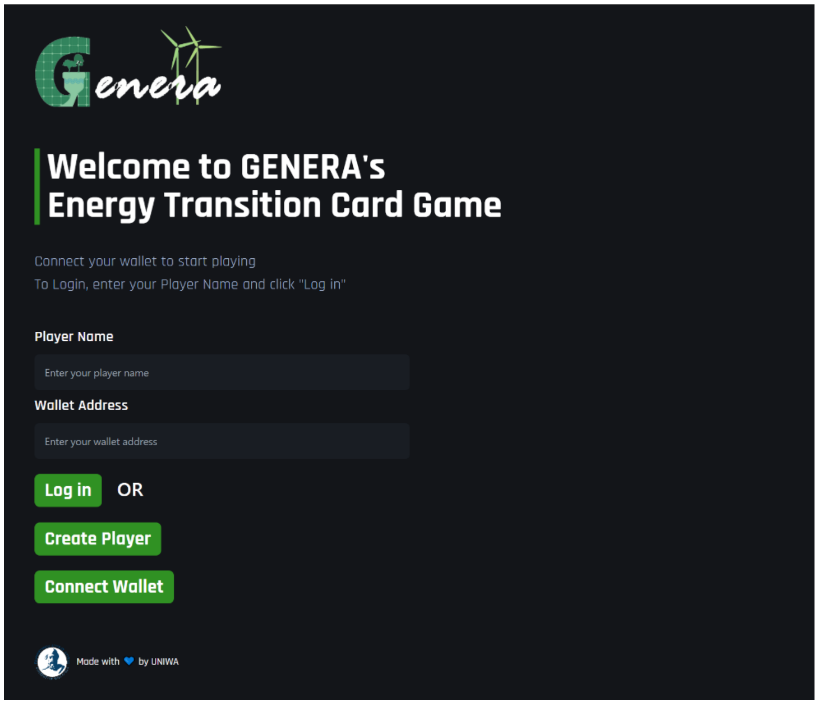

***Figure 13**: The Game's Home Page. Login, Signup and Wallet Connection features are implemented here.*

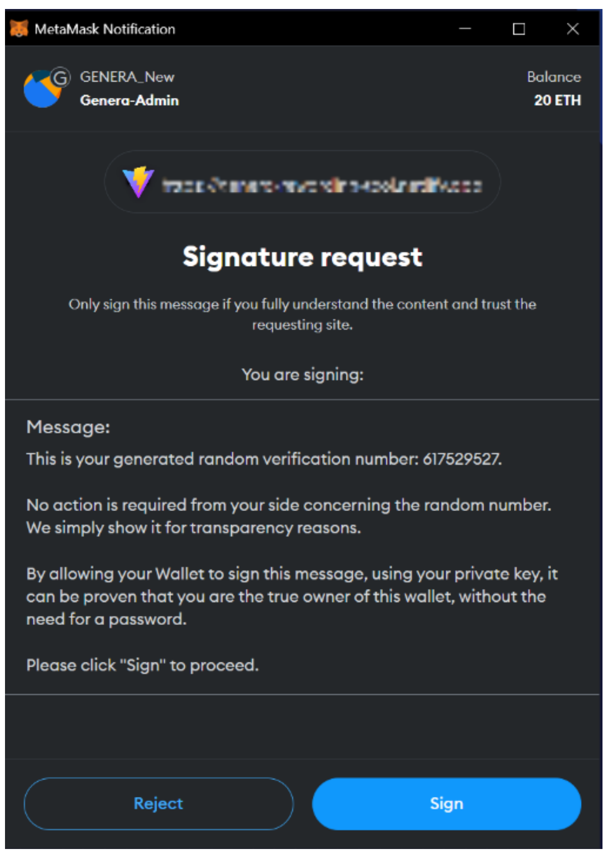

***Figure 14**: Web3 User Authentication through Private Key's Digital Signature Validation.*

Decentralized applications (Dapps) mark a notable shift from traditional centralized apps. The decentralized nature of these apps, while ensuring heightened security and transparency, demands different strategies for user interaction, asset management, and transaction handling. In the section provided, we delve deep into the mechanisms and features that shape the Dapp in context.

1. User Authentication in Dapps:
    - **Personalized User Experience**: Dapps may not mandate account creation, but there's an inherent value in allowing users to create one. By just requesting an alias instead of a public address, the application can foster a more personalized user interaction.
    - **Sign-Up Process**: Rather than a conventional sign-up, this process binds a chosen username to the user's public address within the governing smart contract. Additionally, the process is designed to award users with a bit of the network's native currency, easing their initial interaction with the blockchain.

2. Gasless Transactions:
    - **Automation and Efficiency**: By letting an external entity, like a web server, manage transactions, the game sidesteps the tediousness of manual synchronization from device memory to smart contract.
    - **Cost-Efficiency for Users**: Users are free from spending their ETH for these transactions, making the experience smoother and less restrictive.

3. Digital Asset Ownership with ERC-1155:
    - **Unique Virtual Assets**: The in-game cards, representing different entities, are more than mere digital assets. Their ownership and uniqueness are maintained via ERC-1155 contracts.
    - **Non-Fungibility and Uniqueness**: While the cards might have shared attributes, unique token IDs under the ERC-1155 contract umbrella ensure each card's distinct identity.

4. Ranking and Player Engagement:
    - **Storing and Updating Ranking Score**: The score, an integral component of user engagement, is housed in the GameManager contract. While gasless transactions handle the usual updates, manual updates are an option for users seeking more control.
    - **Encouraging Consistent Interaction**: A disciplinary mechanism is in place, wherein players who remain inactive for five days risk losing progress. This nudges them to stay engaged and regular.

5. Marketplace Dynamics:
    - **Selling a Card**: The seller updates the card's status and pricing in the GameManager contract, also making a reference in the Marketplace contract for efficiency.
    - **Displaying on the UI**: Cards are showcased on the marketplace interface, letting potential buyers peruse through offerings.
    - **Finalizing the Purchase**: A trifecta of sub-actions are executed when a buyer is found. The in-game gold tokens are moved from the buyer to the seller, card ownership shifts to the buyer, and the card’s properties related to the sale are reset.

By intricately weaving these mechanisms and features together, the Dapp offers an engaging, efficient, and secure user experience that marries the best of gaming with the advantages of decentralized systems.

2.3. Rewarding Tool

The Rewarding Tool functions as a Decentralized Application (DApp) and serves as a platform where users can explore and utilize their MyGreenScore (MGS) Token balances. By engaging with the platform's web features, such as the Genera Web3 Game and the Social Forum, users can earn these tokens.

As users amass a significant quantity of these tokens, they have the option to exchange them for various rewards. The nature of these rewards can differ based on the contributing partners of the project. For instance, if a coffee shop decides to participate, they might offer 50 coffee cups as potential rewards.

While the application's main page is open to the public (shown in **Figure 16**), allowing everyone to view the available rewards, only those who connect their cryptocurrency wallets can actively engage, check their MGS token balances, and use these tokens for rewards.

The application is intuitively designed, making it user-friendly even for those unfamiliar with the Web 3.0 environment. This user-friendliness is underscored by a clear three-step guide, encapsulated in checkboxes. This guide elucidates the steps for blockchain wallet installation, linking the wallet with the platform, and switching to the correct network. To further simplify the process, a video tutorial (referenced in **Annex A**) provides an overview of the smart contract operations and guides users on how to navigate the DApp.

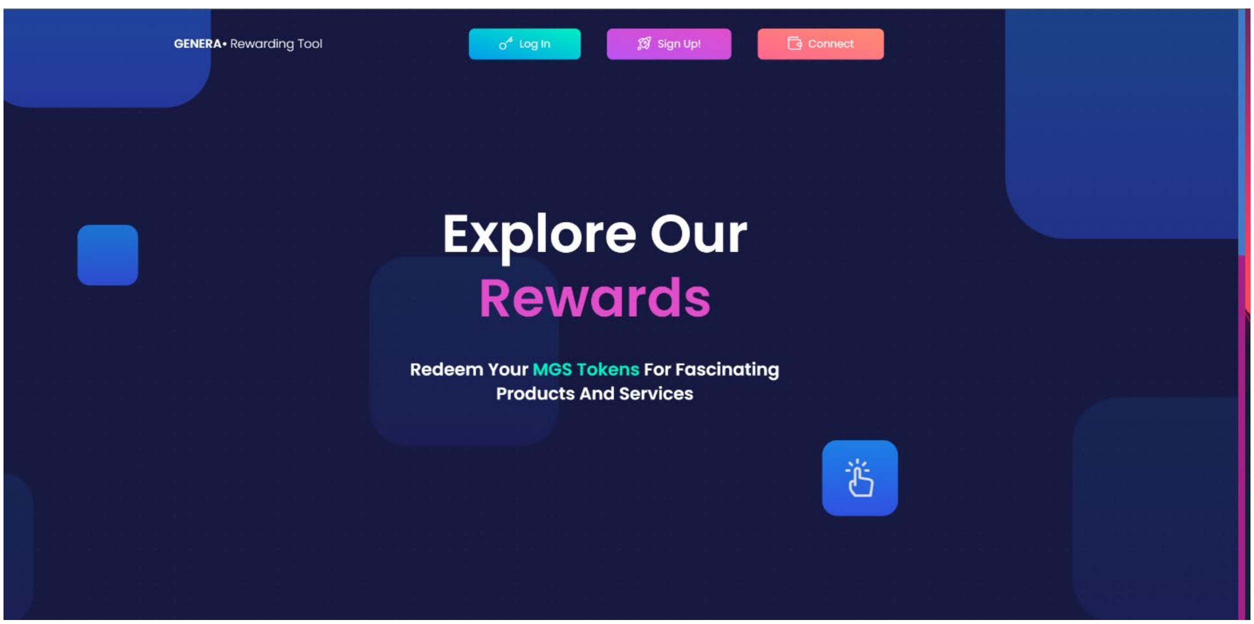

***Figure 15**: The Home Page of the Rewarding Tool Dapp.*

2.3.1. Employed Technologies

This DApp has been carefully designed using a range of the latest and highly respected web technologies in existence today. The technologies incorporated include:

1. **ReactJS**: The most popular open-source, JavaScript library for building user interfaces or UI components, popularly used for constructing single-page applications and handling the view layer in web and mobile applications.

2. **Bootstrap**: A popular open-source front-end framework used for creating responsive and mobile-first websites.

3. **Chart.js**: An open-source library that provides flexible and customizable charts for visualizing data on the web.

4. **React-Aria**: A collection of React Hooks that provides accessible UI primitives for building robust and accessible web applications.

5. **Axios**: A promise-based HTTP client for the browser and Node.js, used for making HTTP requests from JavaScript applications.

6. **Ethers.js**: A JavaScript Library, that is required in order to allow the application to communicate with the blockchain.

7. **Webpack**: A powerful open-source JavaScript module bundler.

8. **Sass**: A preprocessor scripting language that is compiled into CSS, extending its capabilities and features.

2.3.2. Features & Presentation

This application allows users to perform the following actions:

1. Sign-Up
2. Log in
3. Learn about the Platform's Services
4. View available rewards and their requirements
5. Redeem MGS tokens to claim a reward
6. Provides a history of the previously acquired rewards

Let's start by discussing about the **User Authentication** process. In contrast with the traditional web applications, where personal information is required to identify a user entity, in blockchain-powered applications the user is only asked to provide his/her account public address that resides in their crypto wallet (**Figure 17**). The section 2.2.3 of this document contains more information about the workings of this procedure. In some cases, as in this Rewarding application, an alias (username) is also requested. The reason behind it is to enhance the User Experience (UX) [75], rather than referring to the user as a huge string of letters and numbers, a username is shown.

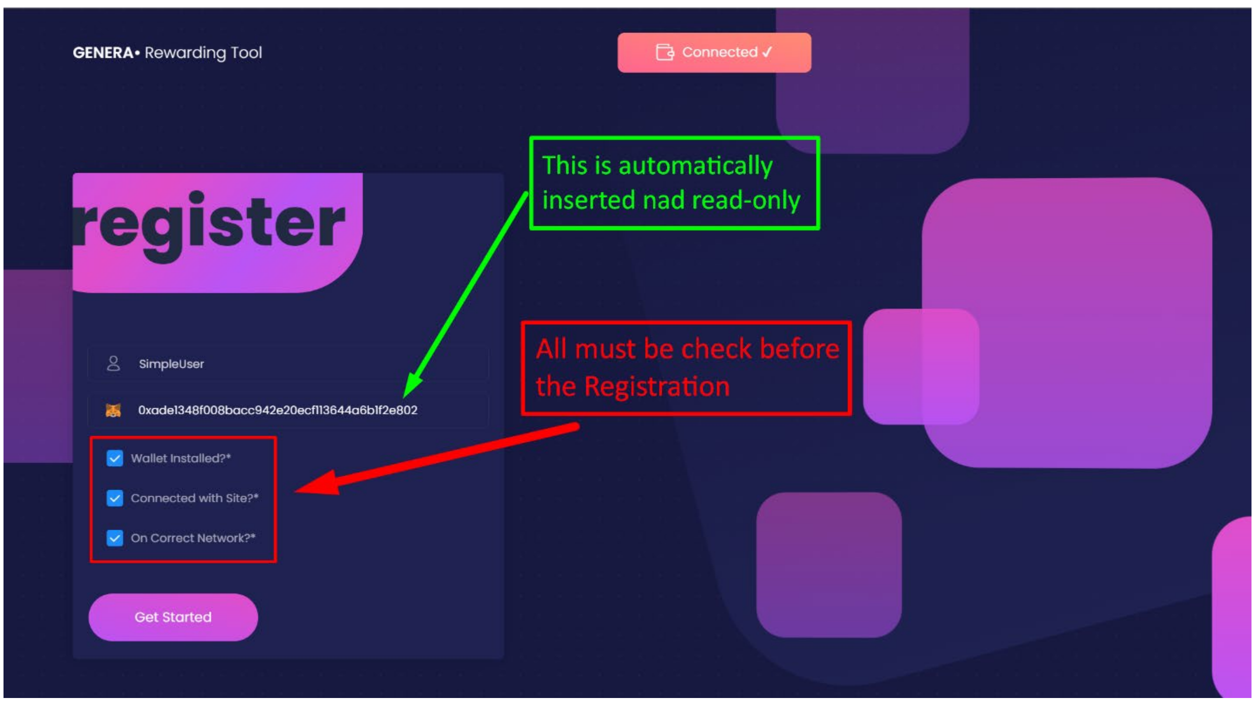

***Figure 16**: Rewarding Tool's Registration Page.*

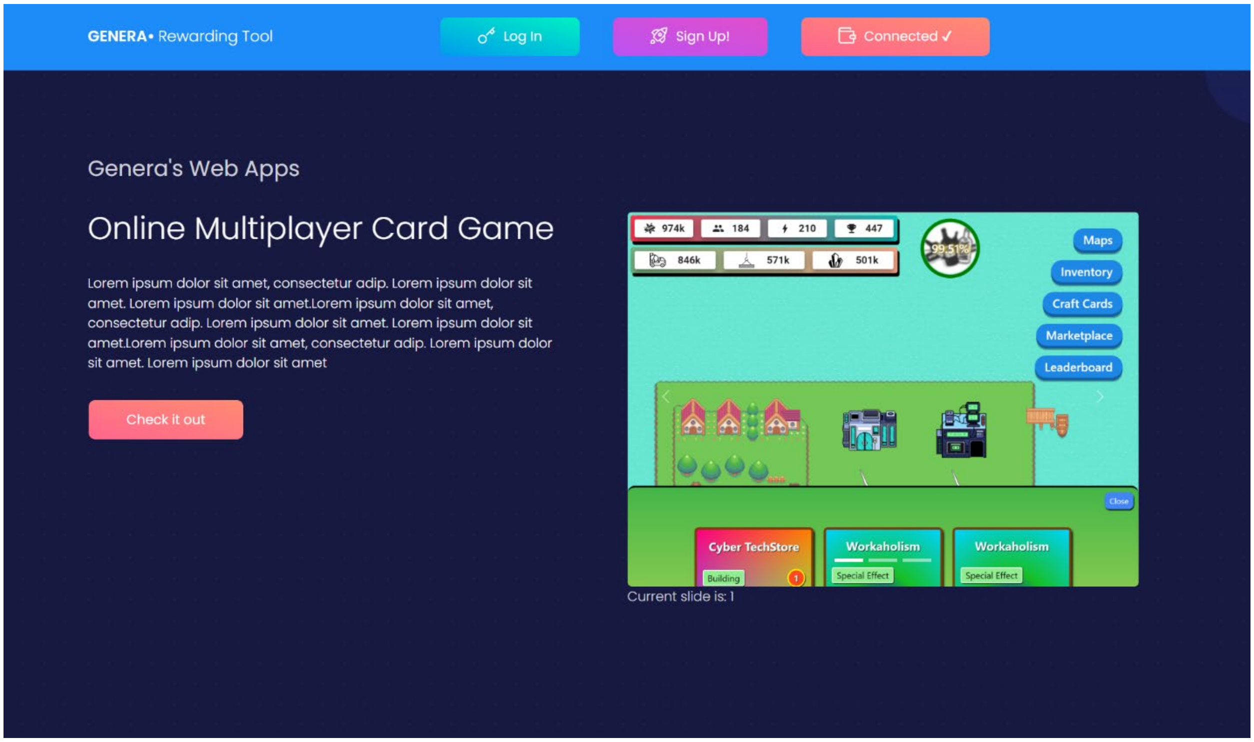

***Figure 17**: Rewarding Tool's Carousel Component.*

Through the *carousel component* (**Figure 18**), located after the site's hero section, the user can be notified of the rest of the platform's services, such as the Social Forum and the Web3 Card Game. Below the carousel, the available rewards are displayed (**Figure 19**).

These rewards possess six properties: an image, a title, a description, a price, a location and an amount. The first four are self-explanatory, regarding the location, it is the island of the shop which is working with the project. For more information, the user can click on a reward and then a popup window renders where a link to the shop's website and its location on the google maps is present. The last property, amount, indicates the number of products or services the shop owner has agreed to provide to the project.

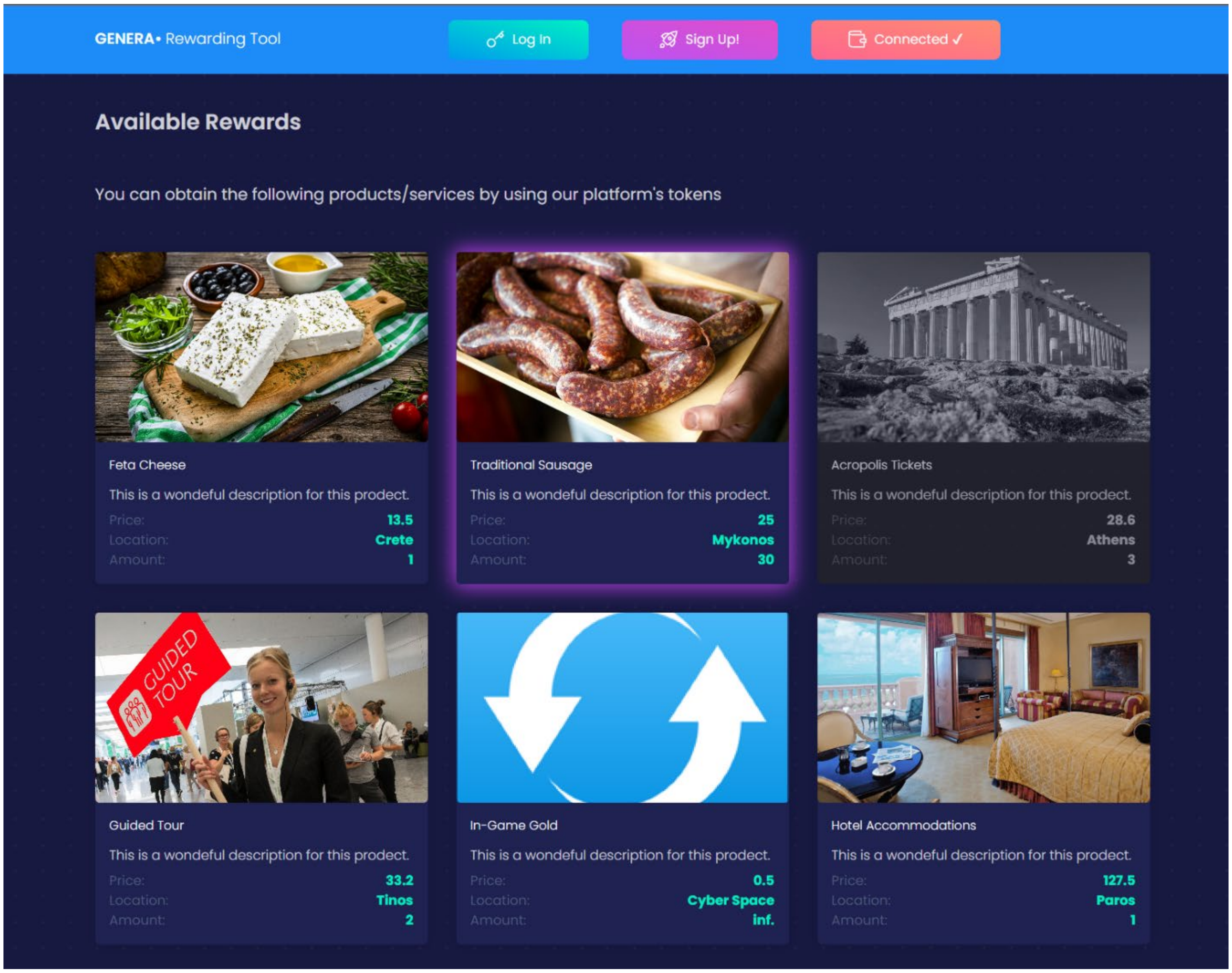

***Figure 18**: The Available Rewards for the Platform's User to precure.*

The **process of redeeming MGS tokens** can be considered the most intriguing part of the application. Obviously, all necessary security precautions must be in place, such as to check if the user is logged in, if the network that the crypto wallet is pointing at is "GENERA" and finally if the user possess the required amount of tokens to claim the reward.

Whether these requirements are met, the application shall initialize **a sequence of three transactions** that the user will have to sign one at a time (**Figure 20**). **The first** one will ask the user to **approve** a number of **MGS tokens** to spent of his/her behalf. This is required because the user's tokens reside in the ERC20 smart contract and not the Rewarding Tool smart contract, therefore the latter needs permission before transferring any of the user's tokens.

Afterwards, the **second transaction** is made from the application's web server. This server works as an Oracle, this term on a high-level means that the server will provide some external data to smart contract on the blockchain. Blockchains are deterministic systems, therefore cannot access the internet or other external sources directly. In this particular case, the external data is a **6-digit random number** produced by Node.js's native crypto module. To pick up where we left of, the web server creates a transaction that will store this random number into the global variable of a smart contract named "Oracle".

Note that this transaction is happening behind the scenes, so the user is not aware of it. Once this transaction is completed, the frontend will initialize the **third and final transaction** (second in the eyes of the user). Here are, the series of actions that are performed:

1. The Rewarding Tool contract **transfers the user's tokens to itself**, like taking cash from a customer and storing it to store's cash register.
2. The Rewarding Tool contract **retrieves the random number** from the Oracle contract.
3. The user's alias and the random number are hashed together to **create a secret and secure user identification hash**. This is required for the validation process which is mentioned later.
4. **This hash is then stored** in an array that is nested within the user's object **in the blockchain**.
5. **The random number**, generated by the web server, **is stored into the user's device**. If this method was neglected and the user lost the 6-digit number, it would impossible to retrieve this number again, therefore the reward would be unclaimable.

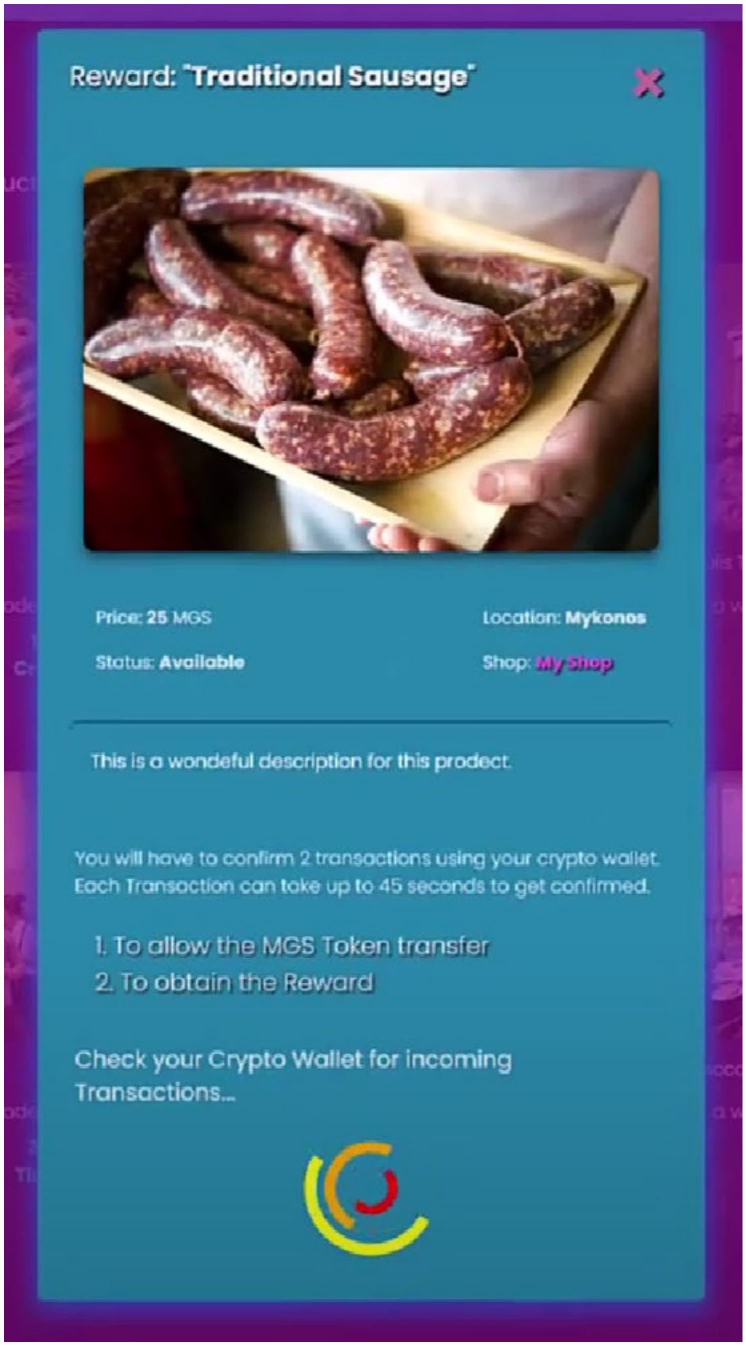

***Figure 19**: MGS Token Redeem Procedure.*

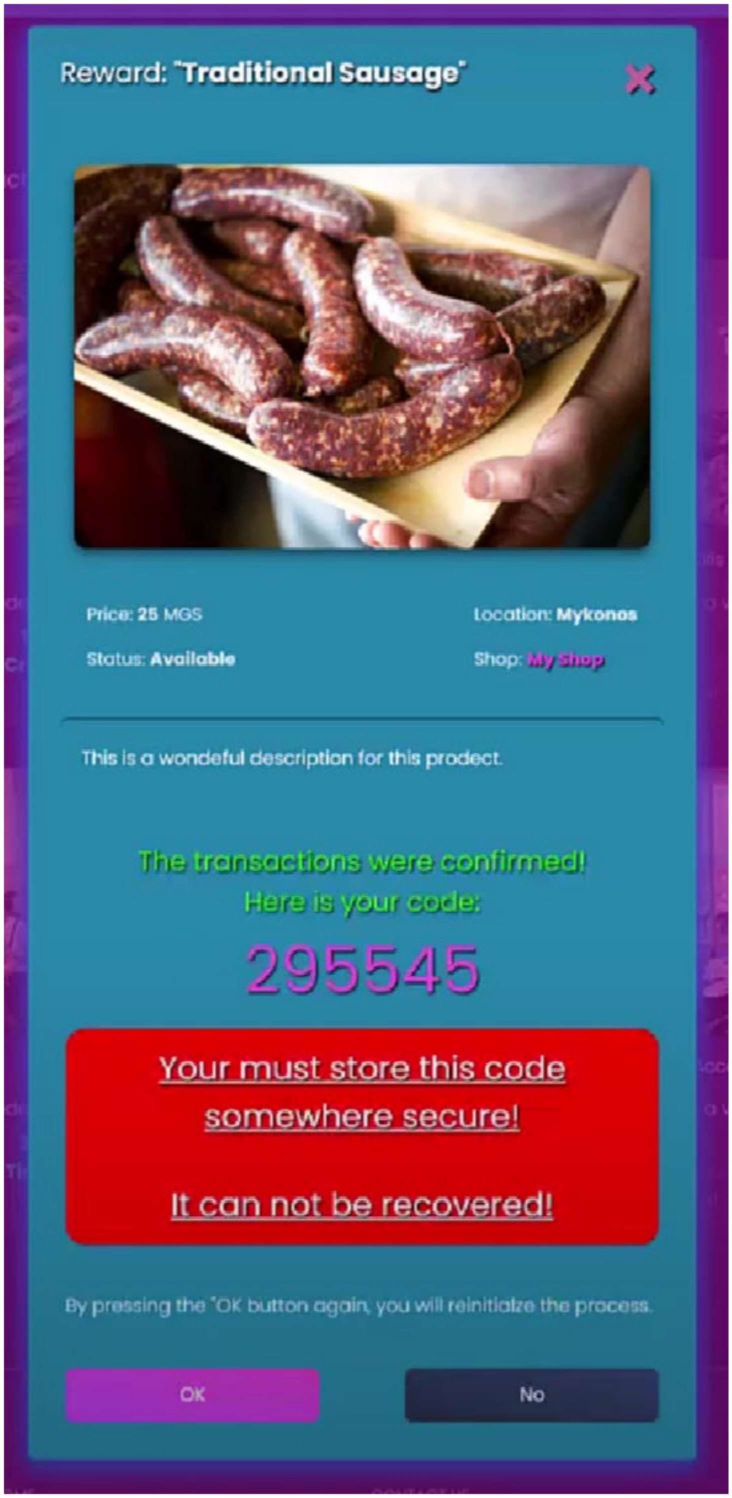

***Figure 20**: The 6-Digit Redeem Code, after a Successful Reward Purchase.*

Once the reward purchase process is finalized, the window's contents change as seen in **Figure 21** the user can view the newly obtained reward in his profile page (**Figure 22**). However, every reward has two stages, at first it is at a pending stage named "Redeemable". This means that the reward is bought by the user, but the user has not yet gone and claim it from the corresponding store. The moment the user visits the shop to claim the physical reward, the validation process begins.

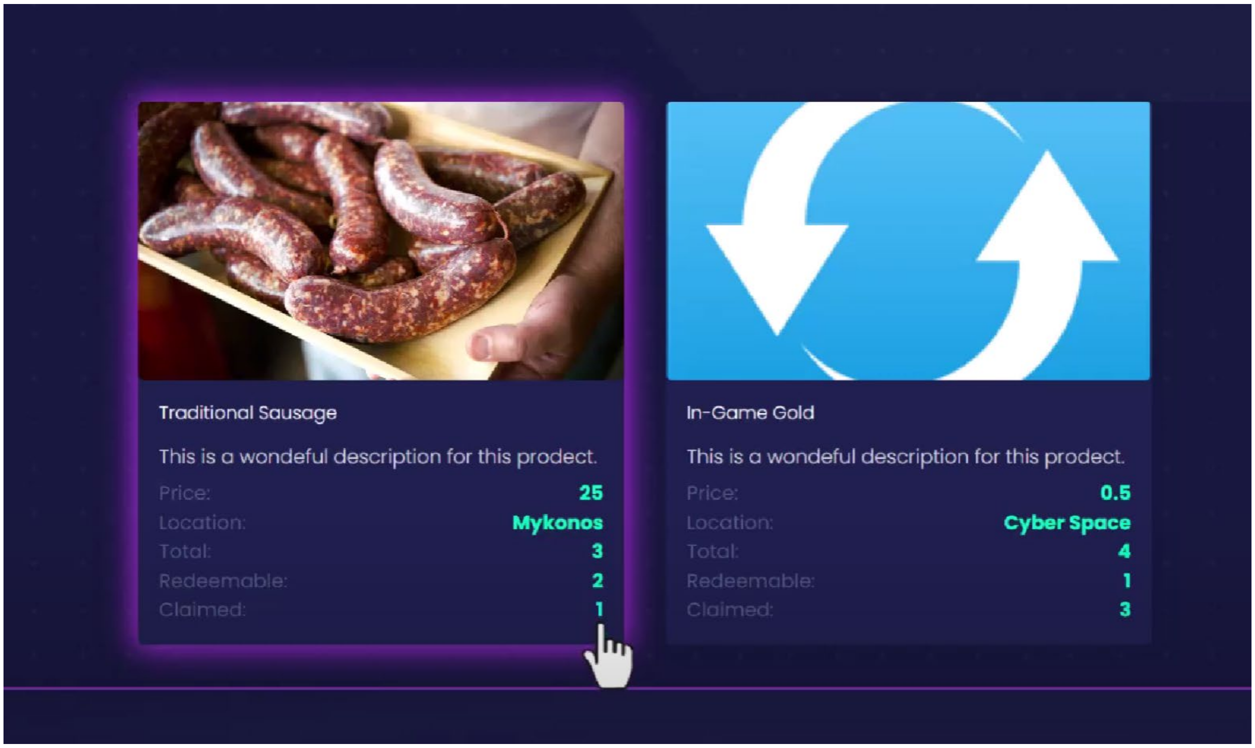

***Figure 21**: The User's Profile Page, where The Purchased Rewards History can be accessed.*

The validation process requires the user to provide his/her username and the 6-digit code to the store's employee (**Figure 23 and 24**). Then we can verify that the person trying to claim the reward is indeed the legitimate one by hashing these two provided values. This hash is then sent to the Rewarding Tool' smart contract through a transaction. A function dedicated for this process is called which simply checks if the hash calculated from the store is the same with the one residing in the user's object. At the end of this process, if the hashes match, a corresponding message is displayed (**Figure 25**) to the shop's employee screen and the reward is marked as "Claimed" which is the second stage that reward can be in. If they do not match the message in **Figure 26** is shown instead.

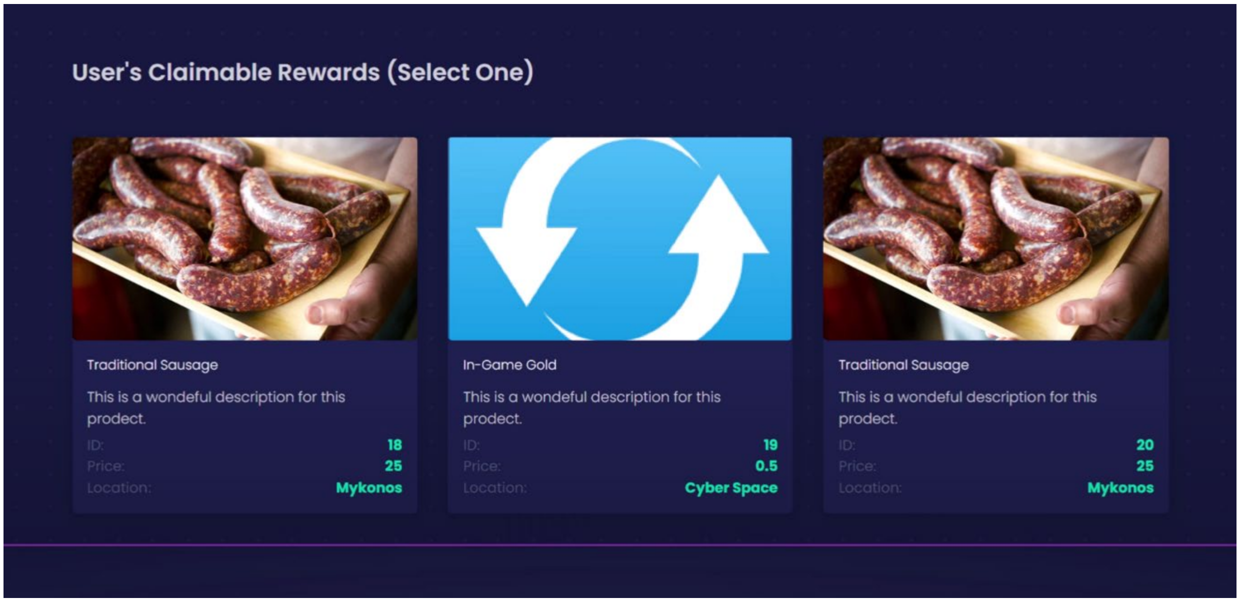

Figure 22*: The UI of the Store's Employee, the fetched User's Rewards.*

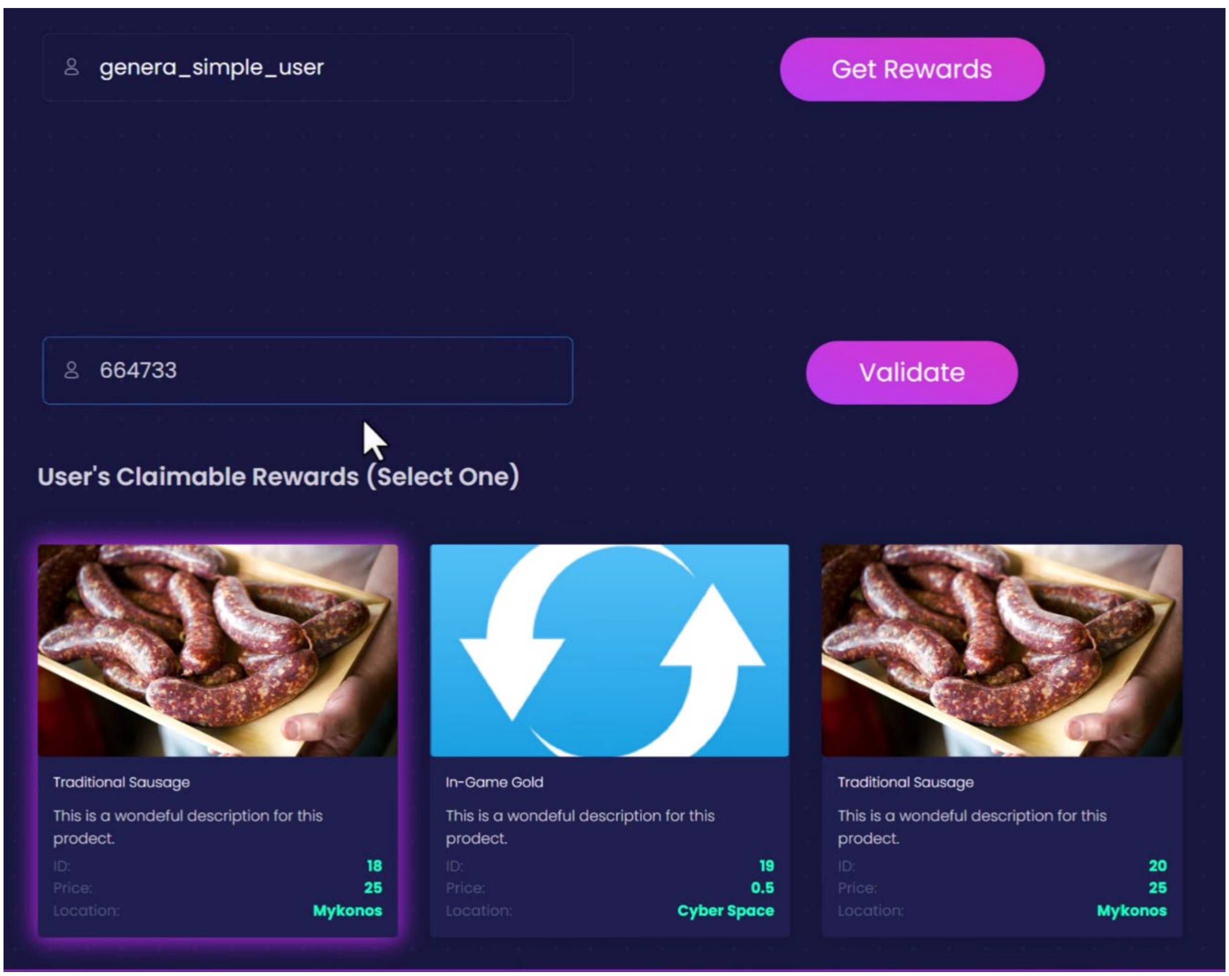

Figure 23*: The UI of the Store's Employee, validation of the 6-Digit Redeem Code.*

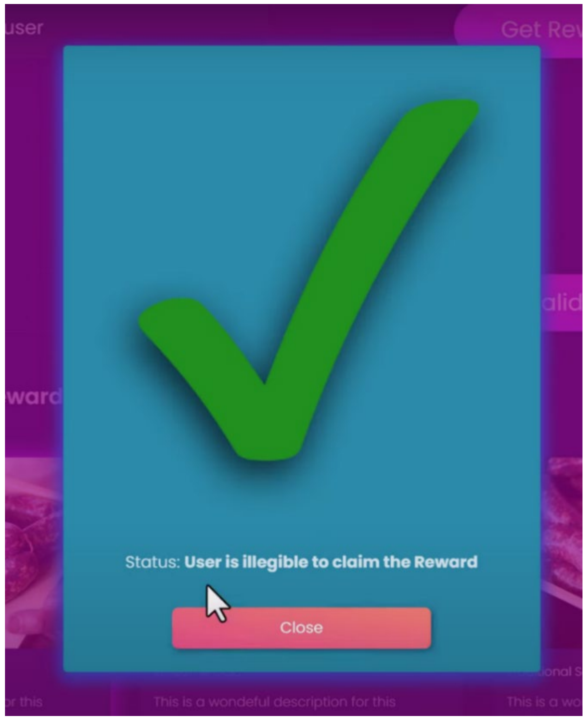

Figure 24*: Success Window, hashes match.*

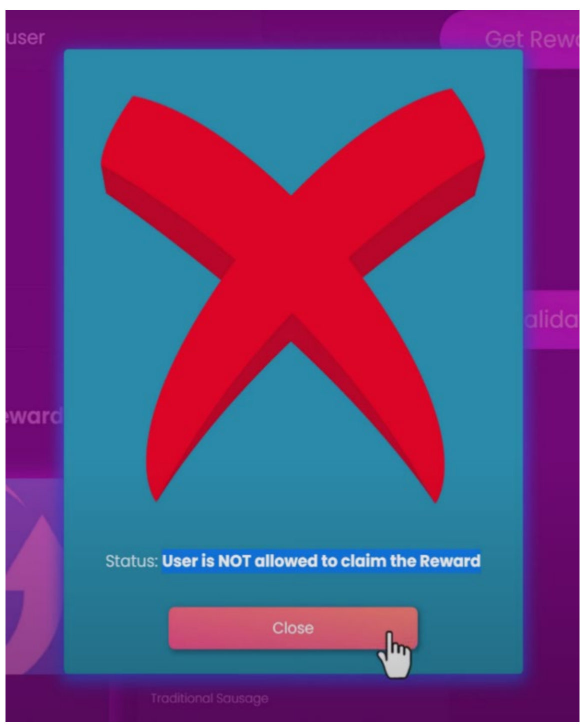

Figure 25*: Failure Window, hashes do not match.*

2.4. Social Forum

The Social Forum is crafted as a web-based platform, designed to bolster the capability of its registered members to delve into project-focused discussions. It stands as a lively, collaborative hub where members can articulate their views on diverse subjects. With tools that facilitate commenting on specific articles or partaking in anonymous polling, users can endorse or critique both the content and feedback from other members. Through this approach, the Forum cultivates an engaging and democratic dialogue on project-centric topics and innovations.

Moreover, user engagements, whether it's a comment or a vote, can be documented on the blockchain. This enables rewarding active users with MGS tokens, further incentivizing their interaction with the platform. It's worth noting that while the wallet integration isn't a prerequisite for Forum engagement, it's essential for those wishing to claim the associated rewards.

2.4.1. Employed Technologies

In this segment, we delve into the design criteria and the ongoing advancements related to the Social Forum Web Application of the Platform.

Given that the hosting site for the Social Forum is anchored in the WordPress infrastructure, the web application is tailored to seamlessly blend with this structure. This divergence in developmental approach from other Web Services is evident in the specifics detailed in this report. Key foundational technologies were handpicked to shape the core of the website.

The primary technologies integrated are:

HTML (HyperText Markup Language): This is the foundational markup language that crafts and structures web documents, delineating their format and organization on the World Wide Web.

CSS (Cascading Style Sheets): Serving as a style-sheet lexicon, CSS details the aesthetic and formatting aspects of HTML documents. It influences the spatial arrangement, shades, typefaces, and more.

JavaScript (ECMAScript): As a versatile and interpreted coding language, JavaScript primarily augments the interactive elements and fosters a richer web content on the client-side of web applications.

Nevertheless, factoring in the blockchain-centric attributes incorporated into the Social Forum, it also functions as a Decentralized Application (DApp). To back this mechanism and amplify user interactions, a series of external modules have been incorporated.

These auxiliary modules are orchestrated to optimize the coding journey and smoothen the liaison between the application's User Interface (UI) and the backend, embodied by the Smart Contracts active on GENERA’s blockchain network. Leveraging these utilities not only refines the developer's procedure but also elevates the operational efficacy of the application.

Outlined below are these vital modules:

- **Tailwind CSS**: This is a forward-thinking CSS infrastructure enriched with preset classes, enabling developers to craft any envisaged design, directly via your annotations.
- **Flowbite**: Heralding as an open-source UI component repository, it is erected atop Tailwind CSS and is an offshoot of the Flowbite Design System.
- **Ethers.js**: As an indispensable JavaScript Library, it facilitates the app's connectivity with the blockchain environment.
- **MetaMask**: Recognized as a universal blockchain wallet and portal to blockchain utilities, it is accessible as both a browser add-on and a mobile application. Its prime utility is in liaising with Ethereum-oriented decentralized applications (DApps).

2.4.2. Features & Presentation

The **main role** of the Forum is to give users the avenue to comment on posts made by its administrators. These administrators are individuals endowed with exclusive permissions to create posts or topics in the Forum. The ability to grant these rights is seamlessly facilitated by the web framework used in the development of the application, which natively includes such access management features.

The selection of Forum Administrators is carefully done to ensure representation of all partners involved in the project. Their responsibility extends to posting content in the native languages of their respective countries, in addition to English content.

The subsequent portion of this section offers a detailed walkthrough of the application's features.

To begin on the application's main page, users must log into the GENERA platform and select the Forum link. This directs them to the initial page of the Forum, depicted in **Figure 27**.

Once there, users can explore and click on any topic that captures their attention, leading them to the detailed page of that specific post.

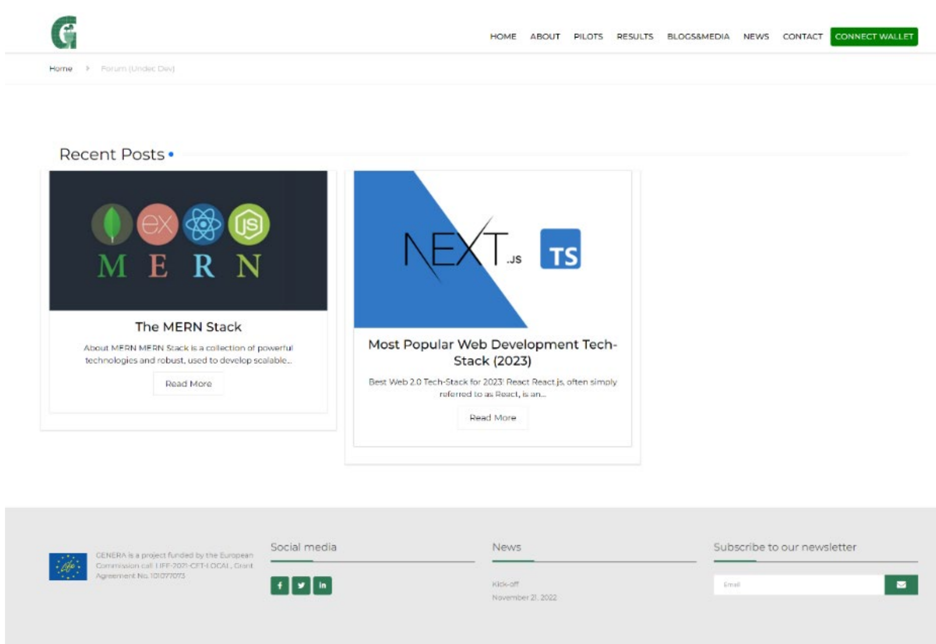

Figure 26*: The Home Page of the Forum's Dapp.*

Once the user reaches this stage, several options are at their disposal:

- ✓ **Content Consumption**: Users can read the main content of the post and explore the existing comments.
- ✓ **Post Voting**: Give feedback on the post by selecting either "Like" or "Dislike".
- ✓ **Comment Voting**: Share opinions on individual comments by choosing either "Like" or "Dislike".
- ✓ **Comment Submission**: Users can contribute to the discussion by adding their comments on the topic at hand.

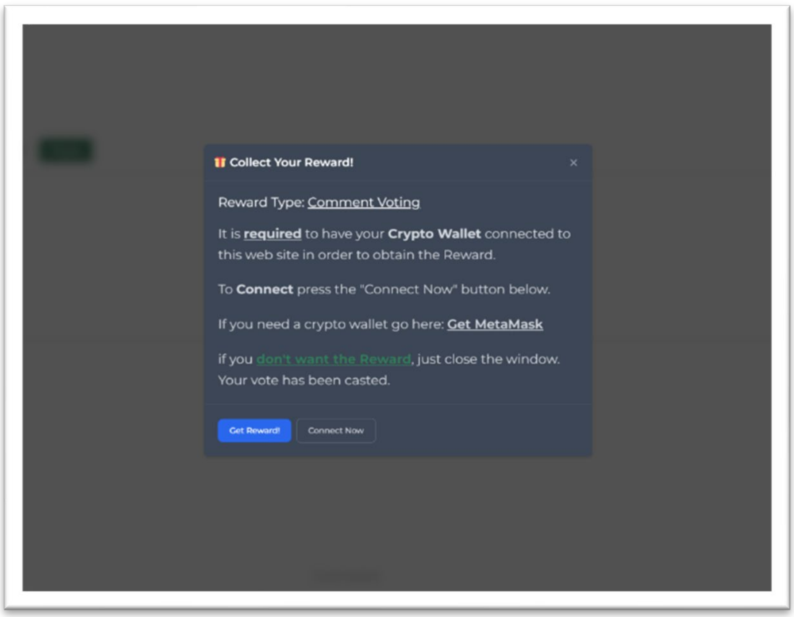

***Figure 27**: Indication Window for the User to Receive MGS Tokens as Awards.*

When executing any of the final three activities, a pop-up notification (or modal) will appear, offering the user a reward. As outlined in the description of this pop-up (refer to **Figure 28**), users need to have a blockchain wallet set up (for instance, MetaMask, which is available as a browser extension and is very user-friendly, [76]) and should also link it to the website for smooth transactions.

Specifically, for MetaMask, once it's installed, users can spot the its logo in the browser's extension area, as depicted in **Figure 29**:

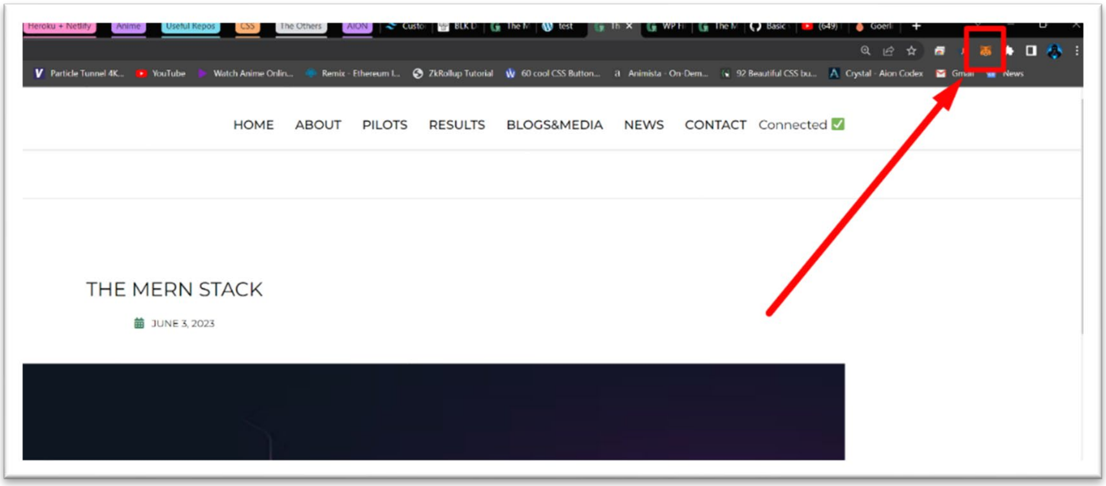

***Figure 28**: The MetaMask's Browser Extension Icon.*

When the user selects the icon, they'll be directed to their MetaMask account, revealing a window that might vary depending on the user, especially concerning the chosen network and the visible ETH balance.

To ensure seamless interaction with the Social Forum web application, users are encouraged to add the GENERA blockchain network details to their wallet and then select it. A handy video tutorial link that breaks down this process can be found in **Annex A**.

It's essential to highlight that if a user opts out of the blockchain-reward mechanism and decides to forfeit their reward, it won't hinder their experience with the other application features. This ensures that users have the freedom to engage with the Forum in any way they please, regardless of their involvement with the platform's reward system or the blockchain.

To give users flexibility in their engagement level, a pop-up appears offering the choice to click on the "Get Reward!" button if they wish to capitalize on this feature. This prompt is showcased in **Figure 30**. Should the user decide not to engage with the blockchain network, even if their wallet is linked, they have the option to close this prompt without any obligations.

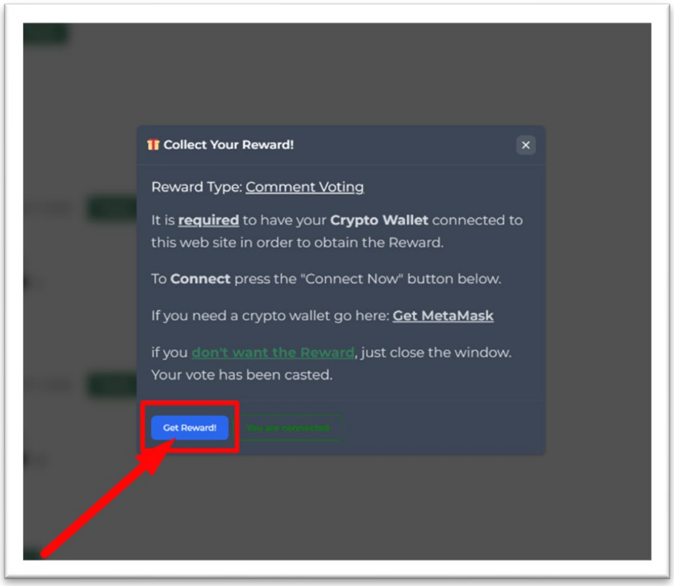

***Figure 29**: Indication Window, in the "Connected" State.*

When the user takes this step, the reward window will vanish, and a new window from the user's digital wallet, MetaMask, will pop up in its place. **Figure 31** depicts this subsequent window, assuming the user employs the MetaMask wallet.

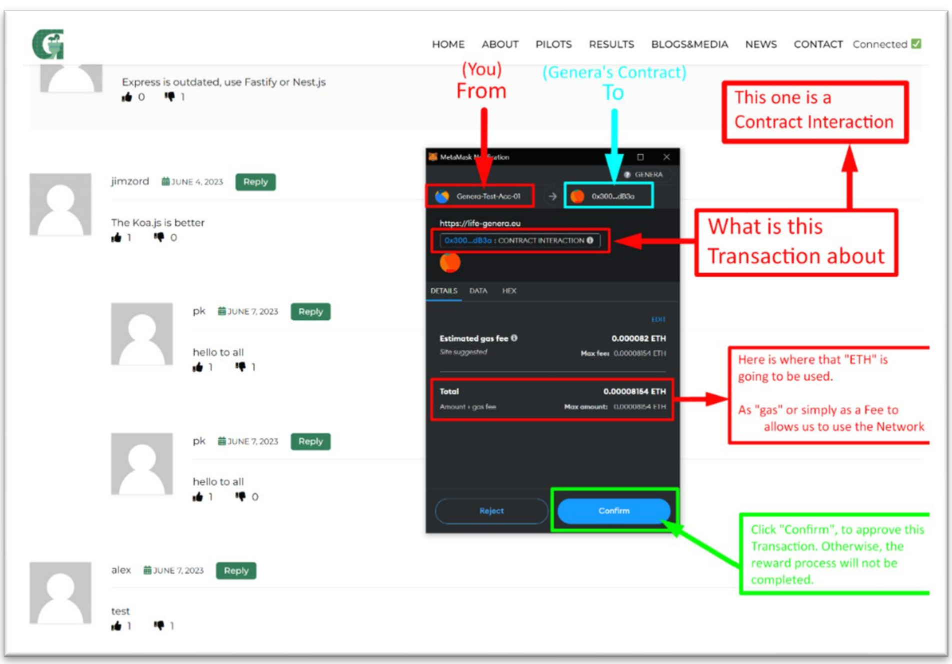

***Figure 30**: The Transaction Prompt Window produced by MetaMask.*

The window offers a comprehensive breakdown of the various menus and choices available within the MetaMask wallet, following the user's consent to claim rewards. In essence, to proceed, the user is required to approve the transaction by clicking on the designated blue button and then sign it to be broadcasted within the GENERA’s blockchain network.

After this step, users are recommended to momentarily hold off on additional actions as the transaction is processed and authenticated in the GENERA's proprietary blockchain network. Once this is finalized, users will be notified through a pop-up alert at the lower right side of their screen. Depending on the transaction's outcome, whether successful or otherwise, an appropriate notification will appear. An example of a successful transaction alert can be seen in **Figure 32**.

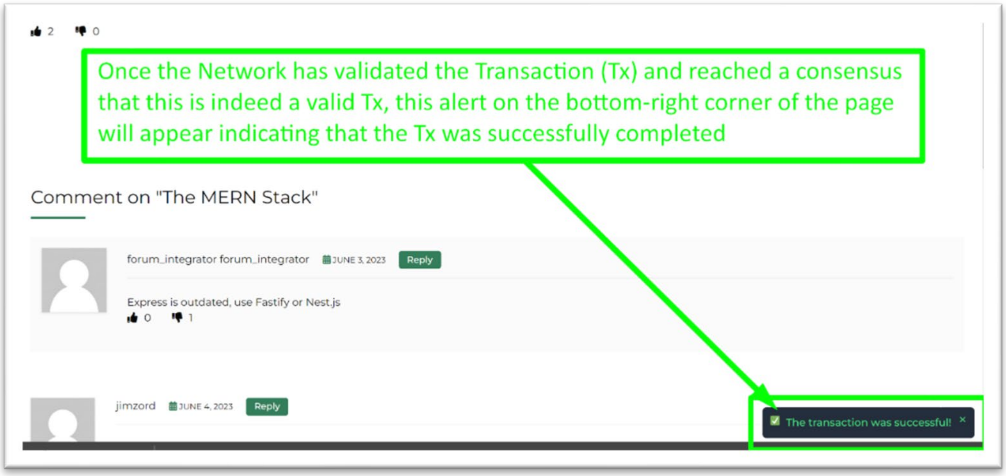

Figure 31*: Alert Message Indicating the Successful Confirmation of the Pending Transaction.*

It's important to highlight that the aforementioned procedure for obtaining rewards through interactions with the GENERA blockchain network remains consistent, regardless of whether the user votes, responds with a comment, or reacts to another user's post.

Section 3:
Findings and Discussion

The current segment of the document offers an examination of the current blockchain gaming domain landscape by analyzing data obtained from the top 150 most popular blockchain games. Furthermore, insights from a pertinent survey that is tasked with grasping the public's perception of blockchain and also collect feedback from the Genera Web3 Game's test users.

The initial subsection, "Analysis of Trending Blockchain Platforms," presents data from notable games and underscores the merits of blockchain integration in gaming. It underlines networks ranking high in game count, active users, total balance, and volume. This analysis aspires to furnish readers with the latest overview of blockchain gaming, accentuating the predominant platforms.

The subsequent subsection, "Survey Analysis," investigates participants' comprehension and perspectives on blockchain technology via a structured survey. It unveils their grasp of core blockchain features, including decentralization, transparency, and security, and delves into their interactions with a particular blockchain-based card game, revealing areas for enhancement and avenues for future advancements.

The final subsection, "Discussion," delineates the merits of blockchain application in gaming, encompassing auditability, fraud deterrence, extendibility, genuine asset ownership, and more. For educational games, benefits entail credential validation, tailored learning through unique tokens, incentivization, and interoperability. The discourse also underscores the Genera Web3 Game's pragmatic and interactive nature, acquainting users with blockchain applications and NFT transactions.

3.1. Analysis of Trending Blockchain Platforms

In 2019, Tian Min [77] and his team embarked on a comprehensive study, delving into the trends of the DApp market and collating a plethora of pertinent data. Their research primarily concentrated on the underlying blockchain platforms rather than the DApps or games themselves. Given the swift advancements in blockchain tech, there was an urge to gather more up-to-date statistics. Consequently, information from the top 150 trending games was extracted utilizing DappRadar [78], mirroring the same source as Tian Min [77].

DappRadar offers a quartet of crucial metrics for every game: supported blockchains, balance, Unique Active Wallets (UAW), and transaction volume. The 'Balance' metric signifies the cumulative worth of assets contained within a DApp's smart contracts. 'UAW' denotes the distinct active wallets that have engaged with or executed transactions with a DApp's smart contracts within a specified span - in this instance, a month. 'Volume' pertains to the monetary value of incoming token transfers from these unique wallets to the smart contracts within a defined timeframe. Subsequent data processing was carried out to convert the amassed data into four visually informative figures.

Insights from **Figure 33** reveal that of the 26 renowned networks. From those, BNB Chain [79], Polygon [32], WAX [80], and Ethereum are home to the largest quantities of games. Singularly among these, WAX focuses exclusively on gaming and utilizes the DPoS consensus methodology, whereas the remaining networks adopt different PoS consensus mechanisms.

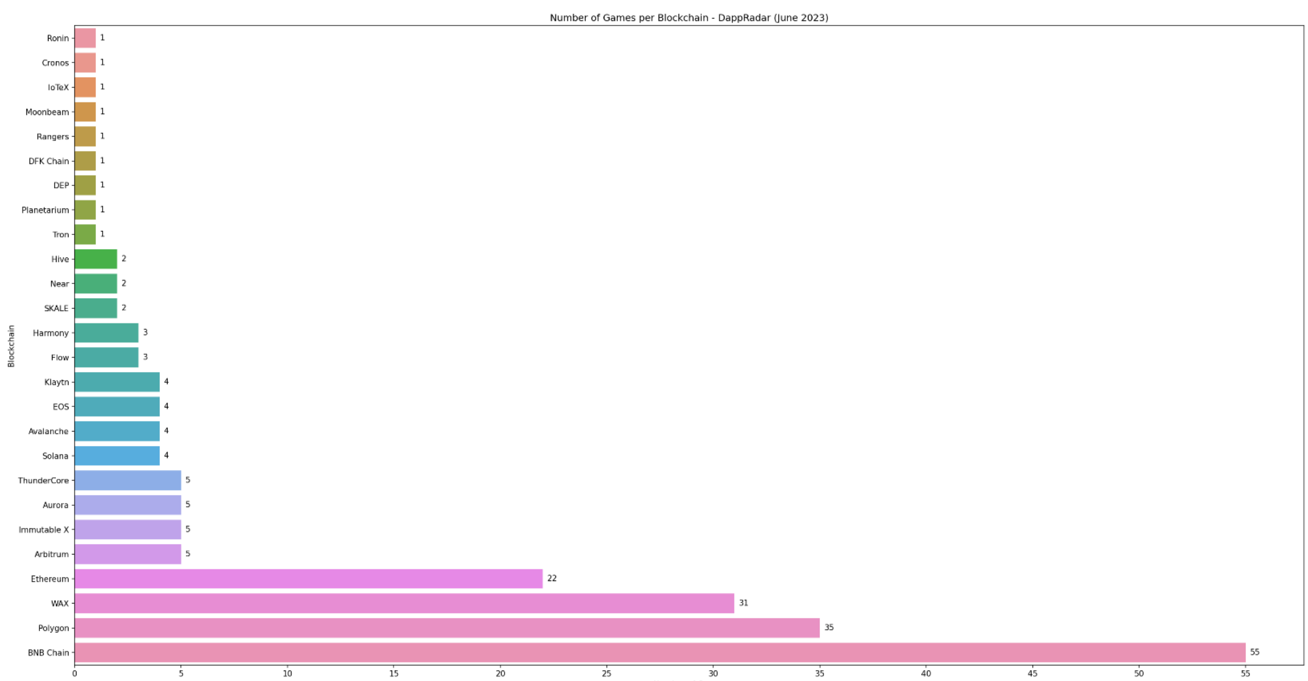

***Figure 32**: The collection of digital games per blockchain network.*

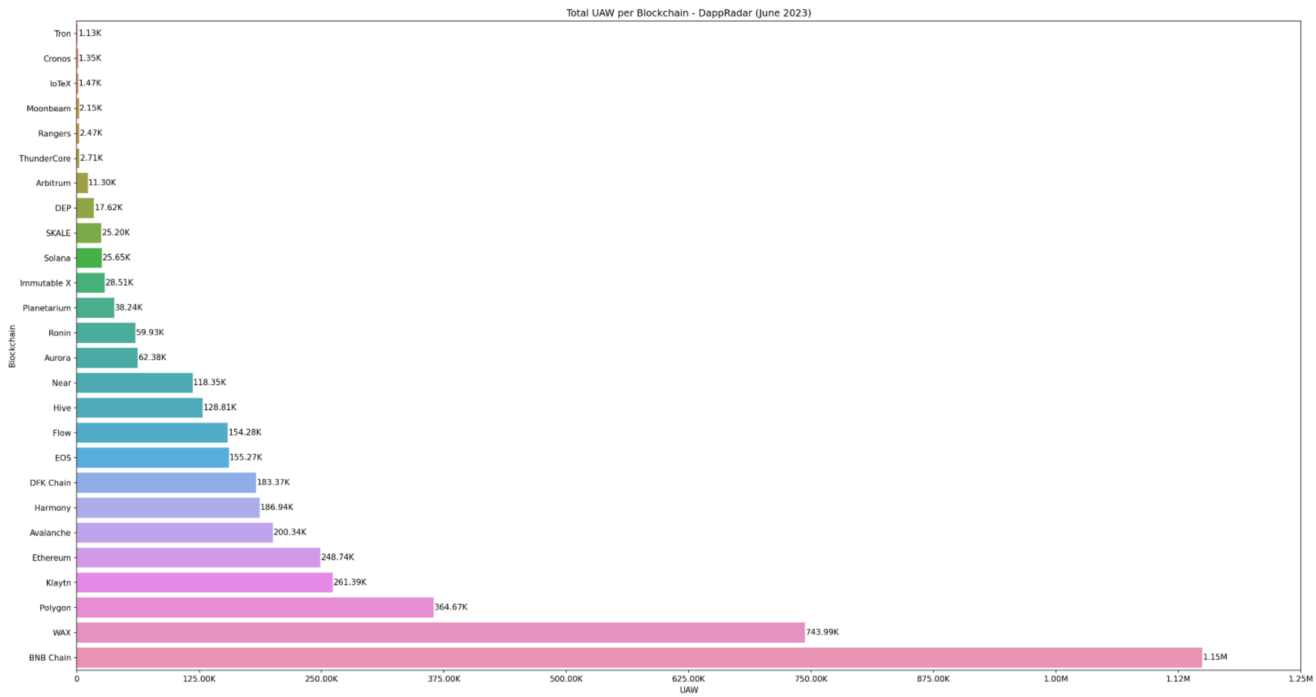

***Figure 33**: The collection of Unique Active Wallets (UAW) per blockchain network.*

As indicated in **Figure 34**, BNB Chain is also at the forefront when considering unique active participants. By analyzing the unique active wallets (UAWs), the rise of certain nascent blockchains becomes evident, especially given their sparse game offerings. For instance, both Near and Hive cater to merely two games apiece, yet they have a commendable count of roughly 120 thousand UAWs.

In the context of the overall balance and transaction volume, Ethereum stands out, with Ronin [81] trailing just behind, as shown in **Figures 35 and 36**. What's intriguing is that Ronin, despite supporting only one game, holds the second position in these two metrics. This single game, Axie Infinity, which took off in 2018, set the stage for the "Play to Earn" paradigm [82], marking a significant milestone in the gaming sector. This model rewards players with tokens for engaging in various in-game tasks. Ronin, at its inception, utilized a PoA structure. However, echoing the user appeal for heightened decentralization, it made a switch to the DPoS framework.

The main thrust of this study aims to furnish readers and peer researchers with a refreshed perspective on the prevailing terrain of blockchain gaming, honing in on the platforms in operation.

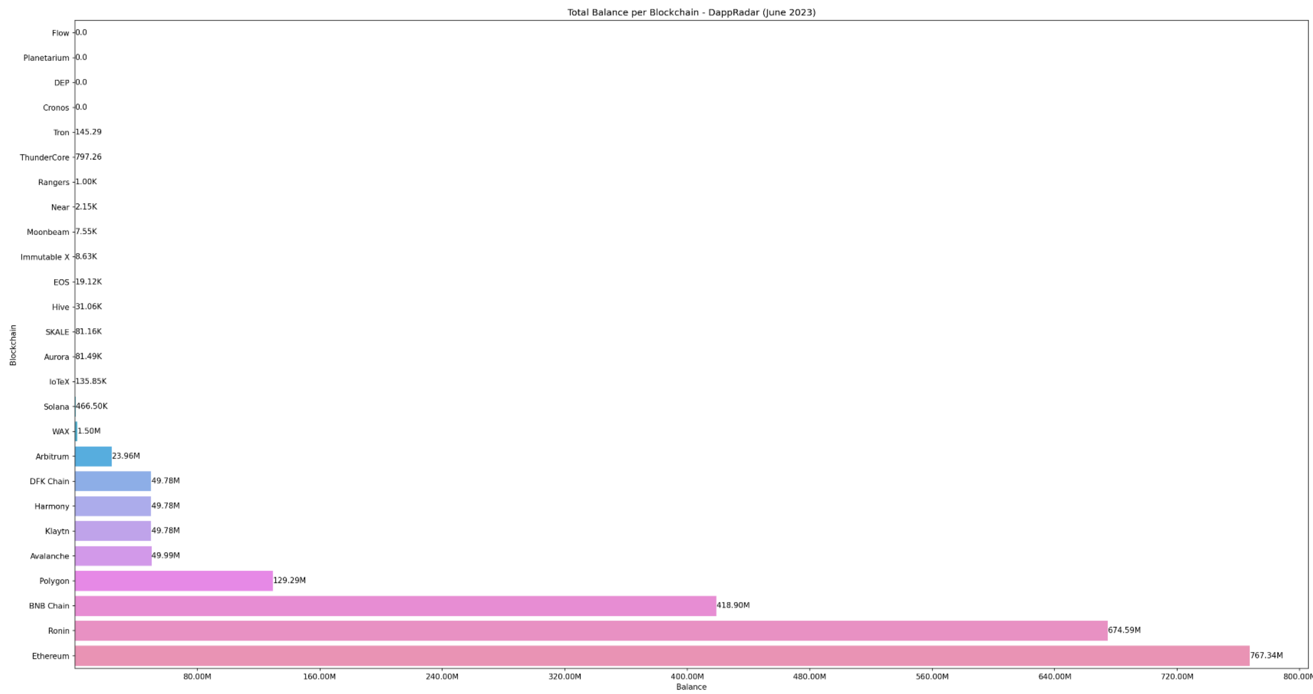

***Figure 34**: The overall dollar contained in each blockchain.*

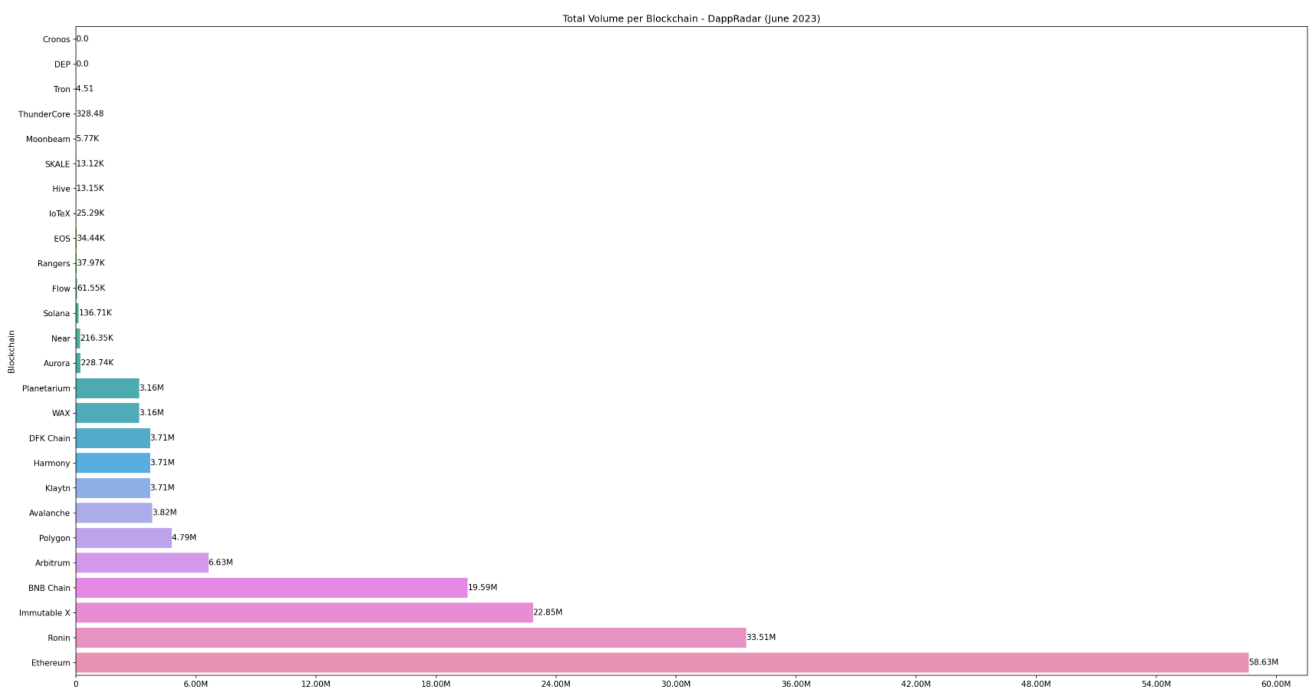

***Figure 35**: The overall dollar amount contained in each blockchain.*

3.2. Survey Analysis

The survey contains 19 questions and includes segments designed to equip participants, who may lack prior understanding of blockchain technology, with the necessary background information. The link for the survey is provided in the Annex A. The survey is structured in two parts: the first section gauges participants' knowledge of blockchain and their willingness to engage with this technology, while the second section is focused on their experience with the Genera Web3 Game. We received a total of 15 responses, with 10 participants unfamiliar with blockchain technology, 3 with some basic understanding, and 2 with an advanced knowledge of its operations.

When participants were asked about their familiarity with "cryptocurrency," 80% acknowledged the term. However, when the questions turned to their understanding of "crypto-wallets" and "public and private keys," only 33.3% responded affirmatively. This gap suggests that even though a significant number of participants are aware of cryptocurrencies, their grasp of the technical details such as crypto-wallets and key management is somewhat lacking. This discovery highlights the need to include educational resources and explanations in the survey to help improve participants' understanding of blockchain technology and its associated terminology.

The following four questions addressed the core features of blockchain technology, with the aim to identify the aspects that may discourage the general public from adopting it. The collected data, illustrated in **Table 1**, sheds light on the participants' perceptions.

Table 1. The common emotional response regarding the use of blockchain technology by the general public.

Produced Feeling	Decentralization	Enhanced Security	Transparency	Privacy & Trustlessness
Excitement	6 (40%)	14 (93.3%)	5 (33.3%)	14 (93.3%)
Fear	0 (0.0%)	0 (0.0%)	5 (33.3%)	0 (0.0%)
Indifference	7 (46.7%)	0 (0.0%)	1 (6.7%)	0 (0.0%)
Insecurity	2 (13.3%)	0 (0.0%)	4 (26.7%)	0 (0.0%)
Security	0 (0.0%)	1 (6.7%)	0 (0.0%)	0 (0.0%)
Happiness	0 (0.0%)	1 (6.7%)	0 (0.0%)	1 (6.7%)

The data shows that with regard to decentralization, most participants remained neutral about its importance in the network. Only two participants expressed concerns over this feature, while the rest seemed to embrace or at least were open to the idea of decentralization.

In terms of blockchain's superior security, there was a unanimous appreciation from all the participants. This universal acclaim underscores the widely acknowledged strength of blockchain: its formidable security mechanisms.

However, the sentiments were mixed when discussing transparency. A mere five participants saw transparency as beneficial, with a larger segment of respondents showcasing apprehension or unease towards it.

The admiration for privacy and the principle of trustlessness matched the positivity seen for enhanced security, reflecting a deep appreciation for these aspects of blockchain. But the contrasting views on transparency hint at potential misconceptions or lack of clarity around what it means in this context, rather than its inherent value.

These findings stress the need for comprehensive education to clarify misconceptions about transparency in blockchain. It's crucial to convey how transparency can elevate security, accountability, and the integrity of data. Emphasizing practical instances where transparency has been a boon can also help alleviate any baseless concerns or misconceptions related to it.

The remaining survey items are illustrated in figures, ranging from **Figure 37** to **Figure 39**, all of which are directly pulled from the Google Forms survey. Each figure presents a visual representation of the feedback, accompanied by the pertinent question in its caption.

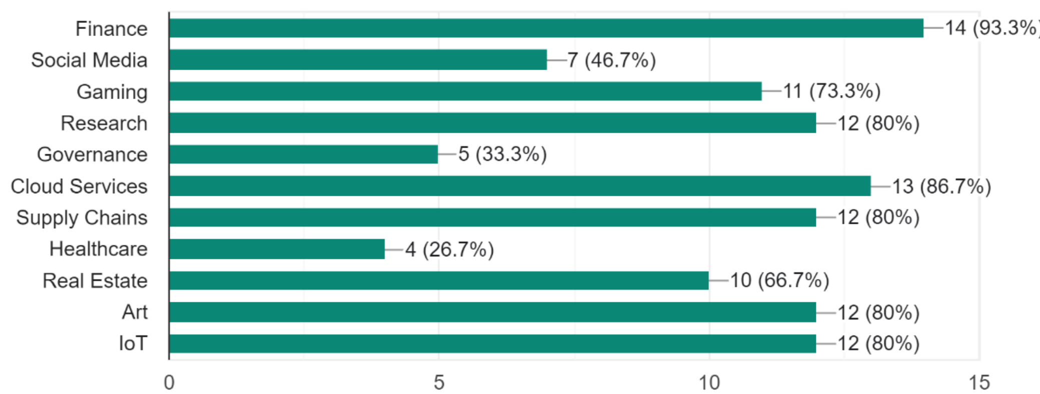

***Figure 36**: Identified Industries That Could Benefit from Implementing Blockchain Technology.*

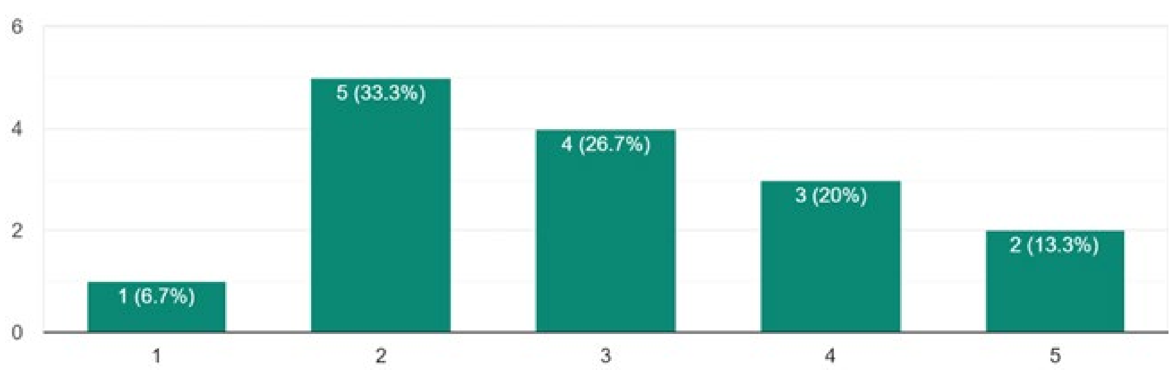

***Figure 37**: Interest Level in Viewing a Tutorial on Blockchain-Based Applications. (1) No Interest, (5) Highly Likely.*

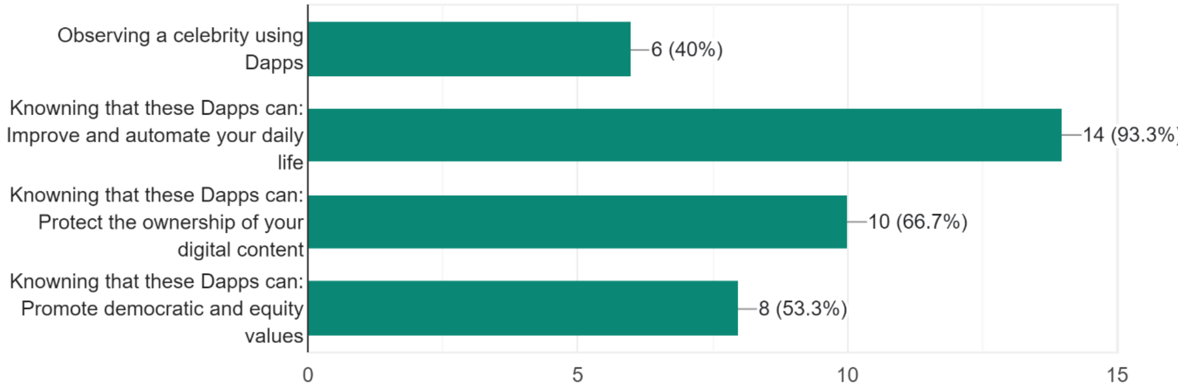

Figure 38*: The drive to Understand and Make Use of Applications Powered by Blockchain.*

Having evaluated participants' comprehension and viewpoints on blockchain technology, the survey transitions to its next section, centered on the game in question. This portion seeks to extract feedback regarding user experiences with the blockchain-driven card game, themed around green energy and responsible resource management. Through scrutinizing their responses, we aim to discern the game's efficacy in melding entertainment with education and its potential to exemplify the feasibility of integrating blockchain in gaming.

From the insights drawn from **Figure 40**, it's clear that a significant portion of participants interacted with the game for a brief duration of less than 10 minutes, with a minority dedicating approximately 30 minutes. Such data suggests a pressing imperative to bolster the game's appeal and maintain player involvement. **Figure 41** further elucidates players' qualms, pinpointing areas of discontent like subpar graphics, insufficient in-game dynamics, and limited content. This feedback resonates with the studies conducted by Iikka Paajala and team, underlining the criticality of balancing the integration of blockchain with the enhancement of traditional gaming elements such as visuals and game mechanics when crafting a blockchain-based game.

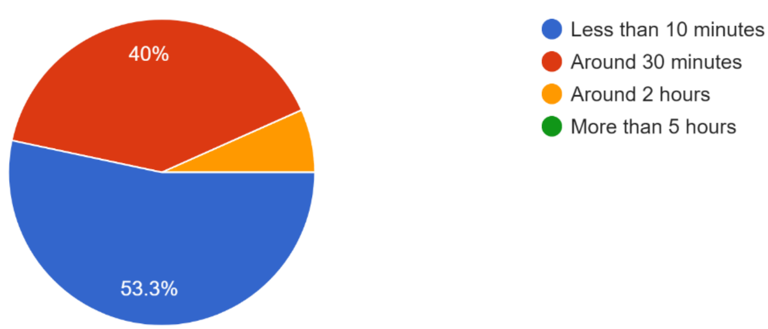

Figure 39*: The Total Amount of Time Spent on the Game.*

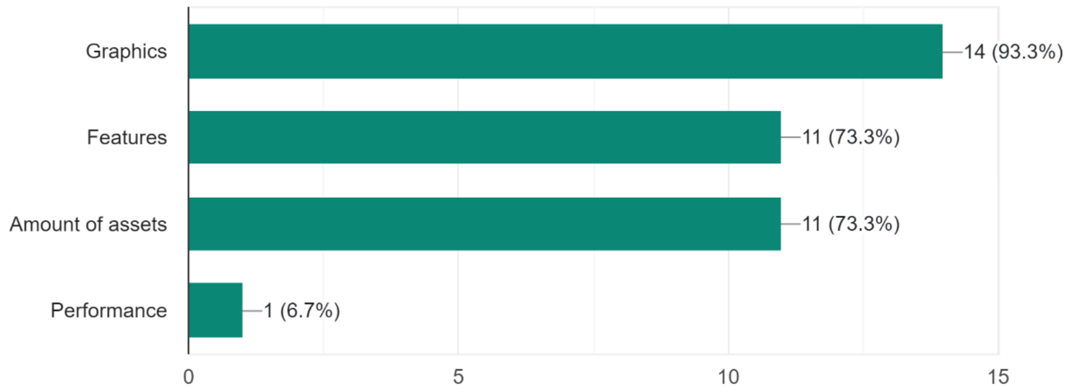

Figure 40*: Feedback Regarding Aspects of the Game that Require Improvements.*

Figures 42 through **44** shed light on the players' interactions with the game as a Dapp, furnishing a holistic perspective of their journey, encompassing steps like crypto-wallet initiation, management of tailored tokens and networks, and digital signature-based user validation.

The data suggests that for the participants, initializing a crypto-wallet was comparatively straightforward vis-à-vis orchestrating custom tokens and networks. This trend is anticipated, given that crypto-wallets are independent entities specifically crafted for digital asset operations. These wallets frequently offer APIs to Dapp creators to augment user experience. Nonetheless, the adeptness in leveraging these APIs and melding them cohesively into the Dapp's UI predominantly rests on the shoulders of the Dapp's developers.

In the realms of genuine asset possession and fraud deterrence, the unanimous sentiment was positive among the participants, manifesting a palpable excitement about these features.

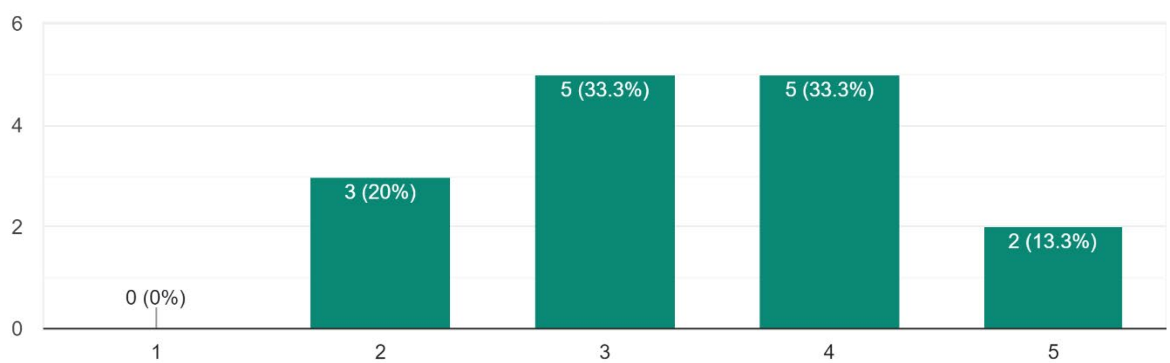

Figure 41*: The Process of Installing and Using a Crypto Wallet. (1) Couldn't Do It, (5) Very Easy.*

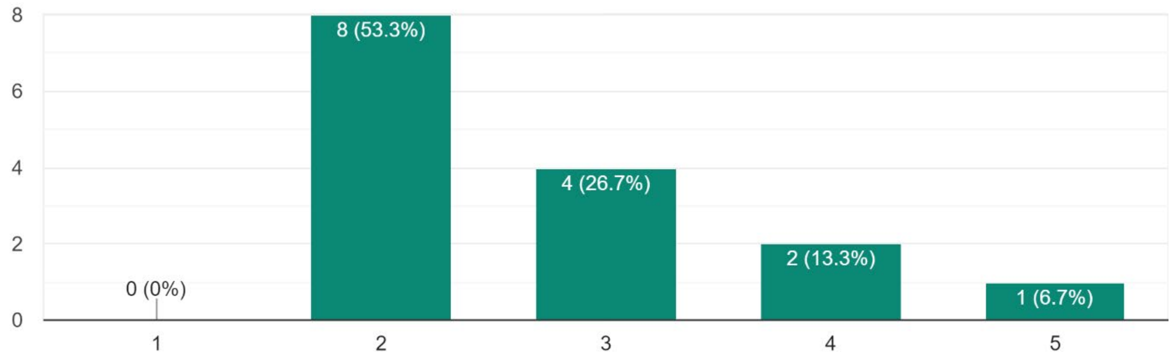

Figure 42*: Integration of Personalized Tokens and Network Connection. (1) Couldn’t Achieve It, (5) Very Simple.*

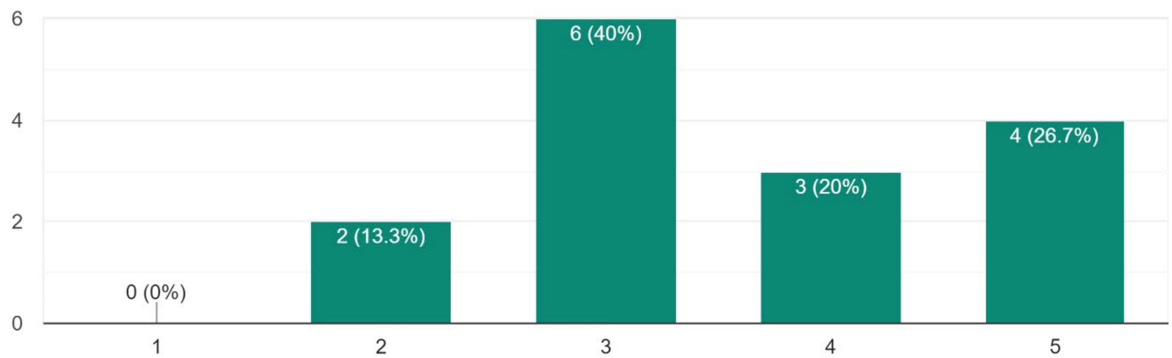

Figure 43*: Authentication for Web3 Users. (1) Favor Traditional Methods, (5) Amazing! Quick and Efficient.*

In the survey's concluding queries, participants weighed in on their enthusiasm for two prospective game enhancements. One question probed their appetite for integrating AI-driven functionalities in upcoming game iterations. Simultaneously, the other sought feedback on creating an additional Dapp geared towards offering a rewards mechanism for other Dapps. The collective feedback was resoundingly affirmative, showcasing a pronounced eagerness for both suggested innovations.

3.3. Discussion

In this section, we'll address the three questions previously mentioned in the document's onset. Focusing on the merits of integrating blockchain technology within the gaming sector, the benefits can be delineated as:

- **Transparency and Immutability**: Gamers can view the game's regulations, allowing them to validate the veracity of developers' promises about the game. Blockchain's permanent transaction record also acts as a safeguard against deceitful claims or misrepresentations.

- **Fraud Deterrence**: Duplication of in-game resources is an issue in numerous online games. However, with blockchain's distinctive token system, each asset gets a unique identifier, mitigating risks of duplication and deceit. This is in contrast to games like Counter-Strike: Global Offensive [83], where item duplication remains problematic.

- **Expandability**: Blockchain augments the adaptability and scalability of game applications. Developers can leverage the game's smart contracts to devise new DApps, introducing fresh features. Examples include DApps visualizing in-game economies or even introducing players' assets into new games, enhancing longevity and potential.

- **Genuine Digital Asset Ownership**: Unlike traditional online games where assets remain on the developer's servers, blockchain guarantees players absolute ownership. This means even if a game server, like Fortnite's [84], shuts down, players retain access to their assets due to blockchain's immutable records.

- **Dynamic Economy**: With blockchain, game economies can evolve. Gamers can accrue interest on assets or trade using automated market maker (AMMs) [85] systems. It resolves challenges many MMORPG [33] players face, like trading restrictions, by granting complete autonomy over digital assets.

- **Data Privacy**: Traditional platforms often ask users for personal data, posing risks of breaches or misuse. Blockchain only necessitates a crypto wallet, ensuring user data remains confidential, with just transaction history and wallet address recorded.

When serious games incorporate blockchain, it brings forth distinctive advantages, boosting engagement and ensuring data integrity, while innovating player reward systems. Delving deeper:

- **Credential Authentication**: Especially beneficial for educational or professional training games, blockchain can track and confirm player milestones. This transparent, permanent record can be used as a digital certification, verified by potential employers or educational bodies.
- **Personalized Learning with Soulbound Tokens**: Originating from traditional games, "soulbound" items are non-transferable, player-specific assets. On blockchain, a soulbound token [34] can symbolize a distinct achievement, potentially enriching the educational experience. Mastery of a concept could unlock content, customized based on individual capabilities.
- **Motivation and Involvement**: Tokens or digital assets can serve as incentives for achieving learning outcomes or showcasing positive behaviors. Their potential real-world worth can heighten motivation.
- **Data Authenticity for Research**: Serious games can facilitate research on learning techniques. Using blockchain ensures transparent, unaltered data, all the while maintaining player anonymity.
- **Cross-Game Integration**: Blockchain can document a player's journey across multiple serious games, enabling skill or progress transfer.
- **Security and Cheating Prevention**: Cheating can undermine serious games' integrity. Blockchain guarantees legitimate in-game accomplishments and secures game data.

Genera Web3 Game <u>is crafted to aid users in understanding blockchain-based application mechanics</u>, offering a blend of education and entertainment. Pre-game preparations for players include:

1. Setting up the renowned cryptocurrency wallet, MetaMask.
2. Incorporating the project's PoA blockchain network and associated in-game tokens.
3. Synchronizing their wallet with the game interface.
4. Creating an in-game account using an alias and starting a transaction to modify the blockchain status. The user isn't charged for this initial transaction.
5. Authenticating using the wallet's private key, certifying the user's ownership of a specific public address.
6. Acquaint players with the process of Trading NFT tokens through the Marketplace.

Conclusion & Future Plans

As this investigative study concludes, the author seeks to convey findings derived from the gathered survey feedback. Suggestions for enhancements and possible applications that could amplify the project's impact and further the advancement of the study's domain are presented.

Concerning the game developed, feedback indicated that augmenting the game's visual aspects might bolster player engagement and retention. In light of this, the author proposes integrating AI-based image generation tools like *OpenAI's Dall-e 2* [86] or *Midjourney* [87] to uplift the game's graphical quality.

Survey respondents highlighted a lack of diversity in cards and in-game functionalities, which they believe curtails their interaction time with the game. Initiatives are in motion to address the card variety concern. For the limited in-game features, the solution might lie in generative AI applications. Tools such as *OpenAI's ChatGPT* [88] and *Google's BARD* [89] could be instrumental in producing AI-driven game content.

The author suggests harnessing these tools to craft questions that promote understanding of renewable energy and resource management. The system ought to challenge users to employ critical thinking in their answers. Once submitted, an AI would grade the response on a scale from 0 to 10, which the game would then use to either reward or penalize the player.

Regarding blockchain gaming, deploying the game's smart contract across multiple blockchain networks could offer insights into determinants of the game's overall efficacy and user experience. The prior section lists prevalent blockchain platforms for gaming. One notably uncharted consensus protocol, the *Proof-of-Play (PoP)* [90], presents a captivating research opportunity.

Furthermore, capitalizing on the blockchain's potential to broaden a DApp's functionality, the author suggests crafting a new app. This app would monitor and visualize digital assets across various games and demonstrate resource and in-game currency movements. In essence, this software would act as a blockchain interpreter, enabling game developers on the blockchain to effortlessly showcase pertinent game statistics to their audience. For this vision to materialize, the app's smart contract should reside on the same blockchain network as the affiliated games.

This study underscored the transformative effects of blockchain tech and DApps on gaming immersion and novelty. The feedback from participants underlined the immense scope for expansion in this realm. As the realms of blockchain and AI advance, they promise to redefine gaming. Our gratitude extends to the study's contributors and the wider gaming and blockchain enthusiasts. We remain committed to delving deeper into this fascinating area.

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Annex A

This Annex serves as a common point to list the links for the GitHub Repositories of the thesis's Dapps, video tutorials that have been produced to help the users understand them and the questionnaire used to obtains the participants' feedback.

Links for code:

1. *Forum: https://github.com/jimzord12/SocialForum-WP-Frontend-Deploy*
2. *Social Serious Game - Frontend: https://github.com/jimzord12/Game-Frontend-Deploy/tree/master*
3. *Social Serious Game – Backend: https://github.com/jimzord12/Game-Backend-Deploy*
4. *Rewarding Tool: https://github.com/jimzord12/RewardingTool-Frontend-Deploy/tree/master*
5. *Smart Contracts: https://github.com/jimzord12/Genera-SmartContracts*

Links for Tutorials:

1. *Serious Blockchain Game: here*
2. *Rewarding Tool: here*
3. *Social Forum: here*

Link for Survey:

- *Serious Blockchain Game Survey: https://docs.google.com/forms/d/1_YyLLX1zGdvXesovUm-vcAQGSyAhzkE1Jo-IEHp-cl8*