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IEEE Standard for Blockchain-Based Green Power Identification Applications

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Developed by the
Blockchain and Distributed Ledgers Committee

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IEEE

IEEE Standard for Blockchain-Based Green Power Identification Applications

Developed by the

Blockchain and Distributed Ledgers Committee
of the
IEEE Computer Society

Approved 6 December 2023

IEEE SA Standards Board

Abstract: Requirements and specifications for using blockchain for green power identification applications are specified in this standard. A technical framework for the planning, design, construction, and operation of green power identification systems is described. The purpose is to improve the efficiency of system interactions, perform life cycle traceability management of green power identification applications, and enhance the efficiency of multi-subject identity authentication for green power identification, thereby improving business efficiency.

Keywords: blockchain, certificate, green electricity, green power, IEEE 3224™

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Introduction

This introduction is not part of IEEE Std 3224™-2023, IEEE Standard for Blockchain-Based Green Power Identification Applications.

This standard specifies requirements and specifications for using blockchain for green power identification applications. It describes a technical framework for the planning, design, construction, and operation of green power identification systems. The purpose is to improve the efficiency of system interactions, perform life cycle traceability management of green power identification applications, and enhance the efficiency of multi-subject identity authentication for green power identification, thereby improving business efficiency.

Contents

IEEE Standard for Blockchain-Based Green Power Identification Applications

1. Overview

This standard enables tracking, traceability and rights conformation throughout the life cycle, while avoiding repeated measurement and accounting. This standard helps to increase green power consumption on a society-wide scale and to further enable low-carbon energy transformation.

1.1 Scope

This standard defines an application model and technical framework for green power identification based on blockchain. This standard also specifies the technical and operation management requirements of green power identification based on blockchain.

1.2 Purpose

The purpose of this standard is to support the use of green power identification whole process data by enabling authenticity and uniqueness of "green power identification." This standard enables tracking, traceability, and rights conformation throughout the life cycle, while avoiding repeated measurements and accounting. Use of this standard supports increased green power consumption in society to further enable low-carbon energy transformation.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).[6,7]

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

[6]The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.
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2. Normative references

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There are no normative references in this standard.

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause. [8]

green electricity certificate: An electronic certificate with unique code identification issued to the renewable energy feed-in tariff of power generation enterprises as the only certificate of green environmental rights and interests.

green power: Electricity generated using specific power generation equipment, by converting renewable energy into electricity with zero or near-zero CO_2 emissions during production.

NOTE—Specific power generation equipment includes wind turbines, photovoltaic generators, etc. According to the relevant policy requirements of the country or region to which they belong, they can be gradually expanded to other eligible power generators.[9]

green power consumption: Consumer behavior that pays for green environmental values by purchasing green power products, green electricity certificates, etc.

green power identification: The digital certificates that evaluate and certify the level of green power consumption behavior according to a unified methodology.

green power product: Electricity supplied to the power grid and generated by renewable energy that meets the relevant policy requirements of the regions.

NOTE—This mainly refers to the online electricity consumption of wind and photovoltaic power generation enterprises, which can be gradually expanded to other eligible power sources according to regional laws, regulations, and requirements.

green power transaction: The medium to long-term trading of electricity targeting green power products which meets the needs of power generation enterprises, power sales companies, and power users to sell and purchase green power products.

3.2 Acronyms and abbreviations

DAG	Directed Acyclic Graphs
IPFS	InterPlanetary File System

[8] *IEEE Standards Dictionary Online* is available at: http://dictionary.ieee.org. An IEEE account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.
[9] Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

4. Stakeholder

4.1 General

The stakeholders of green power identification applications are the relevant participants involved in the development, operation, and service of the green power identification application system, including service users, business platform providers, and blockchain platform providers, as shown in Figure 1.

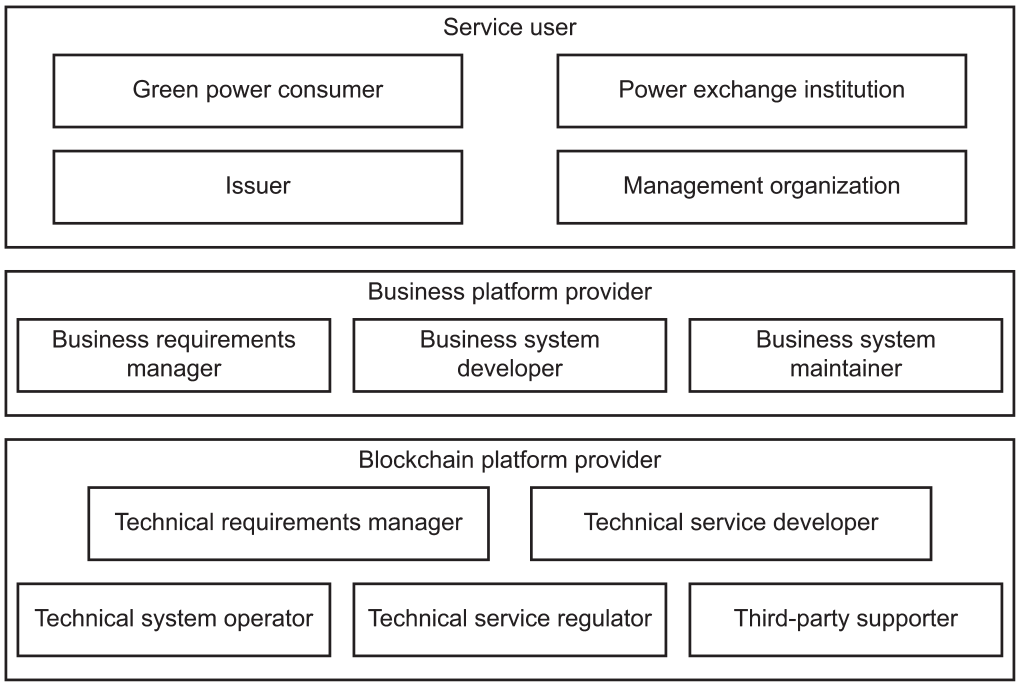

Figure 1—The stakeholder of blockchain green power identification

4.2 Service user

4.2.1 Green power consumer

Green power consumers are electricity consuming enterprises with green electricity consumption and certification needs, willing to pay for green environmental rights, mainly including users who directly participate in or are represented by power selling companies in transactions.

4.2.2 Power exchange institution

A power exchange institution is one that shall do the following:

a) Organizes green power transactions and provides relevant settlement basis

b) Summarizes green power purchase and sales agreements and uniformly manages green power consumption data of green power consumers

c) Complete the issuance and transfer of green electricity certificates based on green power transaction information

4.2.3 Issuer

An issuer shall do the following:

a) Be a legally recognized entity authorized by the government

b) Be responsible for distributing green electricity labels to green electricity users

c) Carry out work under the guidance of rules

An issuer may be any form of legally entity, including a government authority, non-governmental organization, or commercial enterprise.

4.2.4 Management organization

A management organization shall do the following:

a) Be an authorized department

b) Be responsible for setting up a dedicated account for green power consumer to issue green power identification

c) Be responsible for verifying the authenticity of relevant data and information

4.3 Business platform provider

4.3.1 Business requirements manager

The business requirements manager shall be responsible for the requirements design and management of the green power identification business platform by revising and improving the requirements through multi-party coordination to form the final version.

The activities of the business requirements manager shall include, but are not limited to, the following:

a) Identify the core requirements of the system

b) Identify the main functional modules and subdivided functional points

c) Form the exploitable and maintainable requirement profiles

4.3.2 Business system developer

The business system developer shall be responsible for sorting out and improving the business requirements of green power identification services by analyzing the rationality of system requirements and development difficulties. A business system developer also helps ensure the consistency between technical implementation and requirements.The activities of the business system developer shall include, but are not limited to, the following:

a) Design, develop and maintain the green power identification business service system

b) Test and accept relevant functions of blockchain green power identification platform

4.3.3 Business system maintainer

The business system maintainer is responsible for the maintenance process of the green power identification business platform. A business system maintainer helps ensure the availability of platform services, the correct usage of the platform by users, and the follow-up maintenance of the entire process of the platform.

The activities of the business system maintainer shall include the following:

a) Initialize the environment and process

b) Define the operation methods and operation manual

c) Maintain the normal operation of the system

4.4 Blockchain platform provider

4.4.1 Technical requirements manager

The technical requirements manager is responsible for the requirements design and management of blockchain technology that corresponds to the green power identification service so as to support the blockchain the technology provider in subsequent technology development and maintenance.

The activities of the technical requirements manager shall include, but are not limited to, the following:

a) Identify the relevant requirements of blockchain technology.

b) Design a reasonable and complete blockchain technology requirement scheme.

4.4.2 Technical service developer

The technical service developer is responsible for evaluating the rationality and feasibility of blockchain technology requirements and designs. The technical service developer develops and implements technology according to the requirements by ensuring the consistent technical implementation and requirements.

The activities of the technical service developer shall include, but are not limited to, the following:

a) Design, develop and maintain service components or smart contracts in the blockchain system

b) Test and accept relevant functions in the blockchain system

4.4.3 Technical system operator

The technical system operator is responsible for the operation and maintenance process of the blockchain technology service. The technical system operator works to help ensure that the blockchain technology service and infrastructure meet the operational objectives,such as data on chain storage and smart contract execution.

The activities of the technical system operator shall include, but are not limited to, the following:

a) Plan the proper implementation and deployment of blockchain services

b) Provide the whole-process maintenance services of system

4.4.4 Technical service regulator

The technical service regulator is responsible for supervising and managing other technology providers, ensuring the legal and reasonable operation of blockchain services and maintaining trusted blockchain services.

The activities of the technical service regulator shall include, but are not limited to, the following:

a) Monitor and analyze relevant data

b) Set regulatory rules, examine and regulate blockchain services

c) Provide emergency management services

4.4.5 Third-party supporter

The third-party supporter is responsible for improving the external third-party support services of the green power identification service application system (network timing service, certificate authentication service, identity authentication service, etc.) so as to help strengthen the system and improve its functions.

5. Technical framework

The green power identification business system based on blockchain is mainly composed of infrastructure layer, platform layer, data layer, application service layer, and cross-layer service layer. The business system framework is shown in Figure 2.

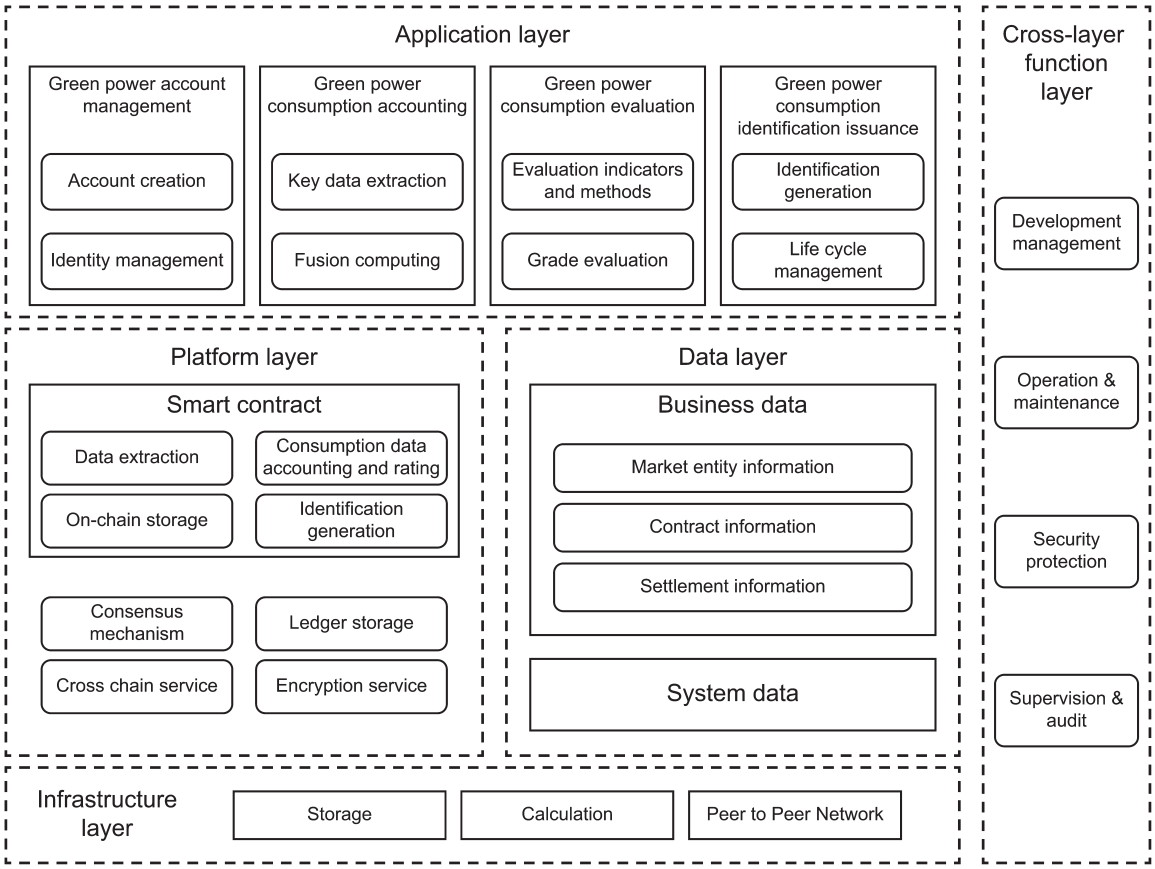

Figure 2—Framework for green power identification application system

5.1 Infrastructure layer

The infrastructure layer is the basis of the blockchain green power identification application system. It provides the required basic environment and components for the data layer, platform layer, and application layer. The infrastructure layer includes storage, calculation, and the peer-to-peer network.

5.1.1 Storage

The storage function component realizes the storage of various types of data generated during blockchain operation. Its functions include improving data reliability through distributed storage of data.

5.1.2 Calculation

The computing function component provides the computing power for the operation of blockchain systems. Its functions shall include the following:

a) Provide operational support for blockchain systems

b) Can be adopted by every node in a peer-to-peer network

5.1.3 Peer-to-peer network

The blockchain system uses distributed peer-to-peer network protocols to organize various network nodes in the blockchain. Its functions shall include the following:

a) Provide efficient and secure peer-to-peer communication

b) Provide multicast capabilities based on peer-to-peer communication

5.2 Data layer

Data layer includes system data and business data. The business data in the system are as follows:

a) *Market entity information:* Market entity information shall include but not limited to the following:
   1) Company name
   2) Company Unified Social Credit Code
   3) Name and ID number of the company's legal representative

b) *Contract information:* Contract information shall include but not limited to the following:
   1) Contract number, contract name, contract type, contract electricity amount, contract start time, contract end time, contract electricity price, and electricity type
   2) Seller code, seller name, seller power generation type, and seller province
   3) Buyer code, buyer name, buyer province, and electricity price
   4) Transmission code, transmission name, transmission province, transmission electricity amount, transmission electricity price, electricity transmission loss rate, and transmission loss discount
   5) Transaction sequence code and transaction sequence name

   NOTE—If there is an agent, the contract information shall also include agent code, agent name, agent province, and agent electricity price.

c) *Settlement information:* Settlement information shall include but not limited to the following:

1) Settlement period, settlement electricity type, settlement number, power market code

2) Settlement electricity quantity, settlement electricity price, settlement electricity charge

3) Corresponding contract number

4) Related green certificate number

5.3 Platform layer

The platform layer realizes the consensus mechanism, smart contract, security mechanism, authority management, encryption service, ledger storage, and cross chain service of the blockchain based on the infrastructure layer and the data layer. It supports the services for the upper-layer application of blockchain. Among them, the smart contract function module performs the following:

a) *Consensus mechanism:* The consensus mechanism functional component completes the consensus process of blockchain network nodes through specific consensus algorithms. Its functions shall include the following:

1) Support multiple nodes to participate in consensus and validation.

2) Support independent nodes to verify the effectiveness of relevant information submitted by blockchain networks.

3) Support the identification and rejection of new or modified information that has not been confirmed by consensus.

4) Have fault tolerances, including non-malicious errors, such as physical or network failures; malicious errors, such as nodes being illegally controlled; and uncontrollable errors, such as nodes generating uncertain behavior.

b) *Ledger storage:* The ledger storage function component enables the storage of distributed data in blockchain. Its functions shall include the following:

1) Support persistent storage of ledger data

2) Support multiple nodes to have delayed complete data

3) Support providing authorized data to nodes

c) *Cross chain service:* Cross chain service management functional components shall achieve cross chain functionality with other chain groups. Its functions shall include the following:

1) Establish connections between blockchain service providers and cross chain service providers based on requests

2) Support the exchange of identity and authentication information between both parties

d) *Encryption service:* The encryption service functional component shall provide encryption algorithms and key security management. Its functions shall include the following:

1) Support symmetric, asymmetric, abstract, hash algorithms, etc.

2) Having a clear key management scheme to ensure the normal operation of the underlying security mechanism of the blockchain

e) *Smart contracts:* The smart contract function component supports generating specific results based on specific inputs under preset rules. Its functions shall include the following:

1) Develop smart contracts that support green power identification applications, including the following:
    i) Data extraction
    ii) On-chain storage
    iii) Accounting and evaluation of consumption data
    iv) Identification generation
2) Support static and dynamic inspection of contract content
3) Provide support for operational carriers, such as virtual machines
4) For smart contracts that interact with external data of the blockchain system, the scope of influence of external data sources shall be limited to the scope of the smart contract and shall not affect the overall operation of the blockchain system.

5.4 Application layer

The application layer is integrated with green power identification related business, and is the specific application of blockchain technology in green power identification. Relevant functions include the following:

a) Green power account management
b) Green power consumption accounting
c) Green power consumption evaluation
d) Green power consumption identification issuance

5.5 Cross-layer function layer

The cross-layer service layer contains functional components that span multiple functional layers to help ensure accurate business management, such as the following:

a) *Development management:* It shall have a combination of service tools for providing development, debugging, and deployment of smart contracts, distributed accounting technology and related applications, building *management* functional components, and testing management functional components.
b) *Operations and maintenance:* It shall have service catalog, policy management, exception and problem management, delivery management, cross-chain service management, ledger management, member management, and other components.
c) *Security protection:* It shall be equipped with authentication and identity management, authorization and security policy management, privacy protection, ledger protection, availability management, and other components.
d) *Supervision and audit:* It shall support governance functional components that support blockchain systems to meet the requirements of governance institutions for blockchain services, as well as audit support functional components that meet the requirements of responsibility identification and event tracing.

6. Application model

The application model of the green power evaluation system is shown in Figure 3. It includes the following four functional modules:

a) *Account registration module:* A green power consumer submits an account establishment application to the management agency for all business operations related to the application for green power identification, including storing the green power consumption data and storing the issued green power identification.

b) *Data extraction and on chain authentication module:* The original data for green power consumption evaluation is extracted from power trading institutions, including green power trading volume and green certificate trading volume.

c) *Accounting for green power consumption data and evaluation of green power consumption behavior module:* Calculate and summarize all green power consumption data in the user's green power account during the evaluation period, then evaluate the total green power consumption data of users during the evaluation period through smart contracts based on the given evaluation algorithm.

d) I*ssuance of green power consumption identification module:* Issue corresponding green power consumption identification to green power consumption users based on their corresponding evaluation levels by smart contracts .

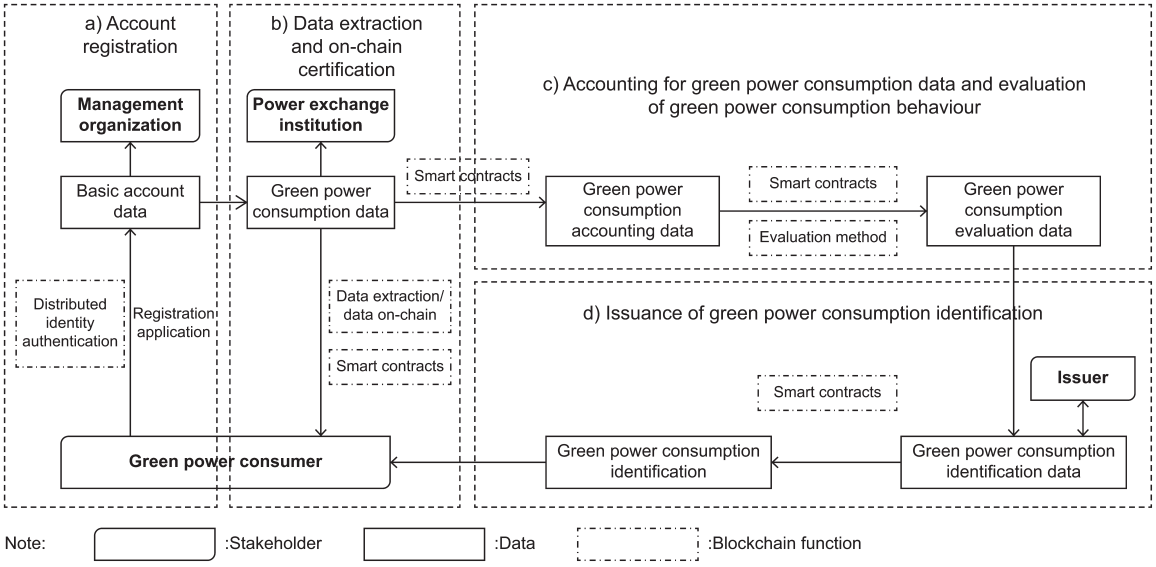

Figure 3—Application model of the blockchain platform for green power identification application

7. Key process

7.1 Account registration

The registration process is as follows:

a) The user initiates a registration application to the management organization through the node terminal application, and the management organization reviews the user's identity information and sends the relevant policies for this registration back to the user.

b) The user terminal node generates a pair of new public and private keys, which are unique to the user, third-party service providers, and blockchain.

c) The blockchain system receives a user’s public key and initiates a registration application with a third-party digital certificate service provider.

d) The third-party service provider registration system pushes account information to the upper level business system of the blockchain, and the business system automatically generates accounts to complete account opening.

e) The user public key is saved and associated with user account information.

f) Provide a response of successful registration to the user.

7.2 Data extraction and on-chain certification

7.2.1 Data extraction requirements

The green power consumption data include off-chain data, on-chain data,and data stored on InterPlanetary File System (IPFS), as follows:

a) For off-chain data, the process for data extracting shall be as follows:

   1) The on-chain smart contract sends a request to the oracle smart contract and receives feedback from the oracle. The information is stored on the blockchain after consensus is reached.

   2) After receiving the request from the on-chain smart contract, the oracle smart contract sends a data retrieval request to the off-chain data source.

   3) The off-chain data source uploads the required data while the oracle smart contract verifies the node. If the node fails verification, the data is requested again.

b) For on-chain data sources, the process for data extracting shall be as follows:

   1) The on-chain smart contract sends a request to the data storage chain smart contract interface.

   2) The data storage chain smart contract sends the required data to the outside.

   3) After receiving the data, the identification evaluation smart contract performs on-chain processing.

c) For data stored on IPFS, the process for extracting green power consumption data shall be as follows:

   1) At the beginning of each evaluation cycle, the on-chain smart contract sends a data request to the IPFS system.

   2) By indexing with keywords, the structure of the Merkel Directed Acyclic Graphs (DAG) of the data is retrieved. The structure of the Merkel DAG is then replaced with the content of the original file to obtain the complete file. The data fields in the file are parsed and processed on-chain.

7.2.2 Technical requirements for evidence preservation

The requirements for evidence preservation shall include, but are not limited to, the following:

a) The system shall support verifying the legality of the on-chain data by calling smart contracts, and once the verification passes, the information shall be stored on the chain for preservation.

b) The evidence preservation period shall be consistent with the business cycle of the information pushed by the power trading platform.

c) The preservation process shall be completed within one minute after the business is triggered.

d) The preservation method shall be content-based.

7.3 Green power consumption accounting and evaluation

After uploading the green power consumption data to the blockchain, it is necessary to summarize and calculate the uploaded green power consumption data with a fixed structure and generate specific calculation values as green power consumption evaluation data.

The requirements for green power consumption accounting and evaluation are as follows:

a) Generate specific values as the green power consumption evaluation score of the company according to the green power consumption certification evaluation formula.

b) In the blockchain system, data calculation shall be performed through a smart contract. Solidity language is recommended to be used for smart contract programming.

d) The evaluation indicators for green power consumption data shall at least include the proportion of green power consumption, and a reasonable value shall be determined as a threshold to rate users' green power consumption.

NOTE—For different industries, different thresholds can also be set by the regulatory authorities based on industry characteristics.

c) Indicators such as green power trading prices and stability of green power consumption may be considered,for evaluation models with multiple evaluation indicators. A weighted calculation method shall be used. For each indicator, the green power consumption evaluation shall be summarized and calculated using the following formula for accounting:

Company j's green power consumption data Y_j is shown in the formula,

$$Y_j = \sum_{i=1}^{n} \alpha_i X_{ji}$$

where

α_i represents X_{ji}'s corresponding weight value, which satisfies $\sum_{i=1}^{n} \alpha_i = 1$
X_{ji} represents the green power consumption index X_i of the company j

7.4 Green power identification issuance requirement

The requirements for generating green power identification are as follows:

a) Carry out on a yearly cycle, i.e., conduct green power consumption assessment, certification, and issuance once a year, and generate a green power consumption identification.

b) The green power identification shall include at least the following information:

   1) Basic green power consumer information

   2) Total green power trading volume

   3) Total green certificate trading volume

   4) Total power consumption

   5) Green power proportion

   6) Effective period

c) Each identifier is valid for one year, i.e., the identifier is valid from the date of generation until the day before the generation date of the next identifier.

d) After each generation of digital identifiers, the previous batch of generated non-fungible token (NFT) digital identifiers shall be recycled;

e) When constructing NFT structures, it is recommended to follow standards such as ERC-721, ERC-1155, NEP-11, etc.

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