

Research on a Blockchain-Based Green Building Materials Traceability and Low-Carbon Certification Platform under the Dual Carbon Strategy — Taking “Green Materials Cloud” as an example

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Abstract: Guided by the “Dual Carbon” strategy, the green building materials industry needs the urgent help of trustworthy and digital transformation. This paper focuses on the “Green Materials Cloud” platform to explore how to use the blockchain technology for tracing green construction materials and supporting low-carbon certification, and creates an integrated services platform based on blockchain database technology for tracking emissions, logistics management, and smart recommendations. This paper analyzes the low carbon certification system, block chain tracking technology, platform function structure, and industry application routes, in order to solve the problems of unclear building material information, low enterprise certification credibility, and low inter-enterprise cooperation level between SMEs to provide effective strategies and reference models for local timber industry green and intelligent transformation and upgrading.

Keywords: Dual carbon strategy; Blockchain; Green building materials; Low carbon certification

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1. Introduction

With the continuous promotion of “dual carbon”, the construction and building material industry must speed up its transformation into a low-carbon development mode, but is generally hampered by lack of low-carbon data, challenges verifying environmental data, and poor cross-supply chain coordination. Blockchain, due to its characteristics of anti-tampering, full process tracking traceability and easy verification, provides reliable technological support for the whole-life cycle management of building materials. In this paper, using the “Green Materials Cloud” platform, we will systematically analyze the role played by blockchain in traceability and carbon emission reduction certificate of green building materials, driving the traditional timber industry towards digitalization, green, and intensive development, and promoting the achievement of the carbon peak goals for the construction sector.

2. Theoretical framework for traceability and certification of green building materials under the dual carbon strategy

2.1. The standard system and indicator composition for low-carbon certification of green building materials

The green building material low carbon identification standards system is the foundation of the identification work, and it also needs to be highly consistent with the country's assessment standards for green construction materials as well as calculation methods for carbon emissions. From the perspective of indicators, it mainly includes the basic indexes like carbon emissions of materials and resources, energy consumed during the production process, discharge pollution, the level of formaldehyde released, material reuse rate, as well as considering the resource utilization rate of sawdust and clean production technology in the assessment system; thus creating an overall tiered, measurable certification program that considers both environmental and low-carbon requirements in light of the realities of how this wood products sector actually produces goods: providing one common standard of measurement for companies' self-certification, third party validation, and platform accreditation; and avoiding divergent certification criteria and definition of information.

A scientifically reasonable, complete indicator set could distinguish the grade of green building material well and prompt enterprises to actively improve their production processes. The indices should have the features that can be collected, calculated, and compared. Through calculating data like carbon emission intensity, by using the above-mentioned criteria such as environmental protection level, energy consumption level, etc., the result of the certificate can be objective and fair. At the same time, the index set needs to be adjusted in time according to domestic and foreign industrial policy changes, new developments in clean energy technology, and so on; it is necessary to include the latest technological innovation results in the index set, such as green bonding agents, etc. Introduce energy-saving drying technology, waste recycling technology, etc., into the assessment system so as to keep pace with industrial technological development in terms of certification criteria. It can provide standard and uniform basic support for blockchain data.

2.2. Operational logic and advantages of blockchain technology in building material traceability

Blockchain working principle for tracking green construction materials is based on blockchain, sequentially records the information of raw material supply, manufacturing, transportation, and product delivery in blockchain to form an unchangeable time sequence; each party has a corresponding permission node; once data is uploaded, it will be encrypted and synchronized on the network ledger and its modification has traceability, thus making it technically impossible to falsify data. During the tracking procedure, consumers and regulators can obtain full-process information through unique identifiers, providing provenance (where it comes from), provenance (where it is going to) and accountability (who is responsible for what actions) in order to create a trustworthy construction materials tracking environment ^[1].

The application of blockchain in the construction materials tracking can bring a series of benefits to improve the information transparency level and management efficiency greatly. First of all, its immutability feature can guarantee the integrity of low-carbon information and environmental indicators, which solves the problem that the old certification is easy to fake and hard to identify. Second, decentralized storage can reduce the risk of a single node failure to improve the stability and safety of the system. Third, it has the characteristics of full process traceability, which is conducive to tracing responsibility, allowing for prompt tracing back to the stage where a problem arose, whether it be one of quality or the environment.

2.3. Limitations and demands imposed by dual carbon objectives on the low-carbon transition of the building materials supply chain

The dual carbon goals have explicit low-carbon requirements for the construction material industry chain, requiring lower carbon emissions throughout the entire process of building materials (raw materials and product manufacturing, transportation, and application), thus driving the transformation from conventional extensive practices to green intensive

practices. The wood processing industry's related requirements concern controls over its energy consumption in production, efficient use of wood products, and recycling of by-products. Industry needs to be weaned off oil and gas, reduce production costs, simplify their production processes, or reduce greenhouse gases emitted per unit produced.

In light of the dual-carbon objectives, the building materials supply chain needs to align with development demands for coordination, openness, and digital transformation. All segments of the supply chain need to break down information barriers, achieve low-carbon data sharing, and enhance overall emission reduction efficiency^[2]. Small and medium-sized enterprises should accelerate their digital transformation by integrating into a unified low-carbon management platform to enable real-time submission of order, production, and carbon emission data.

3. Design of a blockchain-based traceability system for green building materials

3.1. Construction of a full life cycle data collection and blockchain integration mechanism for building materials

The complete life cycle data gathering of construction materials encompasses the entire range of phases, such as extraction/buying of the basic resources, panel processing, environmental testing, warehousing and logistics, and end-of-sales distribution. Key information collection of the system includes carbon emissions, environmental protection level, batch numbers of products produced, inspection results, and transportation records. The acquisition of data mainly depends on the intelligent terminal to upload automatically, and is manually completed to guarantee completeness and correctness in near-real time. Once ready, the information is normalized and stored in the blockchain, where hash encryption produces hash values to ensure that the original data cannot be changed again.

Blockchain integration mechanism adopts the mode of consortium chain, enterprise, platform operator and test institution jointly participate in the maintenance of nodes, each has different operation rights. The enterprises need to produce and upload the carbon emissions; testing institutions verify and confirm the certification information and then record it into the blockchain, whereas the platform provides data aggregation and querying service. After being recorded, the data can be shared among different nodes but also synchronized in each ledger of these nodes to form a continuous and complete traceability chain, which guarantees that the data are both secure and controllable for information sharing, providing users with a trustworthy basis for the data to support queries, regulation checks, and carbon neutrality certificates.

3.2. Storage and query patterns for traceable information under distributed ledgers

The traceability information is distributed on several different nodes within a blockchain distributed ledger to prevent the risk of losing or manipulating traceability information as when storing it centrally. The distributed ledger is arranged over time and separated into business processes, where each block contains a hash value from the previous block, which forms an interlinked data structure. With a huge amount of building material information, the platform adopts a lightweight structure, namely storing core data on the blockchain but attaching data to the cloud, which improves the performance of the system without compromising its security, as well as reducing the nodes' storage burden.

The design of the traceability query function focuses on simplification, convenience, and speed to provide users with convenient methods for obtaining traceability information through scanning the product's QR code or inputting the serial number in the query platform directly, and displaying the result graphically. such as materials, manufacturing process, carbon reduction test report and green product certification information, etc. All can be intuitively understood by non-professionals; the ability to query history records or verify different information meets multiple demands (e.g., business reconciliations, regulatory audits, and consumer protections) that increase the utility and value of a tracing service.

3.3. Traceability node permission management and data security protection solution

The traceability node permission adopts a hierarchical authority mechanism, granting operation permissions according

to the role of participants in order to make responsibilities clear and control orderly. The manufacturing enterprise has the authority to request uploading or modifying data; certification inspection right for the test institution; operation and maintenance right of the platform operator; node management right, while customers only have the permission to query but not modify. The permission assignment is automatically implemented by a smart contract, preventing illegal operations and data leaks, as well as guaranteeing correct use of the data at every node.

Data Security: The proposed DSAS is comprised of the encryption mechanism, authentication and authorization system as well as intrusion detection system; The network communication between the nodes is secured using secure channel protocol so that eavesdropping or will not occur while transmitting messages in networks; data are de-identified so that sensitive company data is not exposed; suspicious access or large-scale edit events are detected, immediately raising alarms and lockout actions when dangers are detected^[3].

4. Research on the functional architecture of the green building materials low-carbon certification platform

4.1. Design of the automatic verification module for low-carbon data accounting and certification information

Low-carbon data computing unit, based on the national carbon account method and combined with the characteristics of wood processing enterprises to automatically collect data such as power consumption, carbon emission factor of each process resource, etc., calculate the amount of carbon emissions in terms of unit products, generate a carbon footprints map report; it also includes built-in low-carbon certification standard libraries to compare the calculation results with the relevant grades, enabling quick decision on whether a product meets green and low-carbon requirements, reducing manual calculation mistakes as well as improving certificate effectiveness. The calculation results are synchronized into the blockchain for confirmation, traceability, and verification of the results.

The automatic certificate authentication block connects to the database API of test agencies in order to verify certificates like green certificates, carbon footprint information, certificates of raw materials, etc. Based on the difference between the blockchain and the materials provided by enterprises, it can identify false information and fake data, automatically denying invalid applications, and providing feedback on the reason for the denial. The latter is a substitute for manual validation: significantly reducing certification timeframes, lowering corporate costs, and improving the validity of certification results, in other words, providing trustworthy information to consumers when they are choosing what green products to use in their buildings.

4.2. Implementation of 3D modeling and intelligent recommendation function for low-carbon building materials

The 3D modeling function enables customers to upload the floor plan or draw out the space layout themselves; then our system will automatically generate the corresponding 3D scene model according to the building structure and interior design style, in which panels are matched with suitable specifications and textures for each object in the model. Customers can modify the material, colors, and location online to see what the decoration appearance of the house will be. The modeling stage also takes into account low-carbon information about the building material, providing the environmental rating and carbon emission information together with a visualized expression so that the material selection and low-carbon design can be integrated easily.

The smart suggestion function recommends panels to the user by selecting and matching the product according to the user's preference range, price range, floor plan, etc., and low-carbon requirements using the algorithm model. This module receives information on users' interactions, which are used to construct individual preference profiles, and then provides accurate suggestions based on the green building material database; this suggestion focuses on materials that have high environmental ratings and low carbon emissions: accompanied with complete traceable information and certificate reports,

which can help users to recognize the high quality of green building products; solve “material selection is difficult and lack of environmental perception”, to improve the user’s use experience and platform service level.

4.3. Establishment of intelligent order splitting and supply chain collaborative scheduling mechanism

Intelligent Order Decomposition Module. This module is used to decompose customized orders for home decoration or engineering projects, which can automatically analyze the details like panel dimensions, quantities, manufacturing processes, and environmental requirements to break down the whole customized order into standard productions that can be mass-produced. It also makes smart matching and optimization of orders based on careful consideration of many factors such as manufacturer’s production ability, geographical location, low carbon rating, energy consumption level, and assigns decomposed sub-orders to proper manufacturers exactly, which can schedule small-batch, multi-shipment, and customized orders. The order assignment problem, it aims to balance production efficiency and low-carbon emission reduction goals, favoring companies that consume less power, produce fewer emissions, and have more uniform managerial controls.

The integrated supply chain coordination mechanism can realize the overall integration and timely sharing of order information, production process information, transportation information, and greenhouse gas emissions information. The manufacturing company can obtain the latest dynamic information on customer demand and supply time, and they are able to plan scientific production in a way that minimizes idle capacity and raw materials waste. Through centralised scheduling and routing algorithms, the platform uniformly plans logistics distribution routes to reduce transportation energy consumption and emission of carbon dioxide, as well as facilitate wood scraps exchange and resources recycling between enterprises; thus substantially increasing the area’s resource use efficiency ^[4].

5. Platform implementation applications and industrial low-carbon development pathways

5.1. Construction of green building materials database and information visualization display

The Green Building Materials Database System provides data about various products such as E0-grade panels, formaldehyde-free glue panels, low-carbon engineering boards, recycle base sheet; it can collect key information including environmental index etc. carbon footprint information of manufacturers, third-party certificates, and end-to-end tracking data in a consistent format according to the types of materials used, rating system, usage scope, carbon reduction certification etc., and constantly updates the database with the most recent industry standards. Green materials technology and green building certification policy ensure that it is timely, accurate, and comprehensive, providing a solid foundation of data support for the platform’s carbon data calculation, smart recommendation, automatic certification, etc., and providing the scientific basis for enterprise production optimization and industry-level low-carbon development analysis.

Data Visualization: To make the complicated industry data more readable and understandable, we use some visual methods to display this data, like charts, 3D models, and process animations, turning abstract numbers of emissions, comparative environmental performances, and full life cycle traceable processes into easy-to-understand contents for general users, which enable the user to clearly read overall environmental information and low carbon performance in the whole product life cycle; enterprises are able to track dynamic variations of the production’s energy consumption and CO₂ emissions from the visualization dashboard; while policy makers can easily track the general low carbon trend of developing region panel industry.

5.2. Digital transformation adaptation solution for small and medium-sized plate enterprises

To support real-life needs of small- and medium-sized plate manufacturers (weak digital background, limited investment in funds, and lack of technical talents), the platform can provide lightweight, low-cost, easy-to-use digitalization solutions, with simplified access APIs and uniform business processes, allowing for the quick incorporation of production data, orders, and carbon data without major capital investment in new equipment. This system has employed its own technical

personnel to provide elementary user instruction, remote assistance, and helpdesk support to enable workers to rapidly learn how to use the systems and effectively capture, transmit, and record production data, carbon emission data, and environmental monitoring data to the blockchain.

At the same time, this solution also supports enterprises in organizing their flexible production and coordinating orders between enterprises. By smartly decomposing the orders and optimally matching, it helps SMEs process the distributed customized orders effectively, greatly enhancing the equipment capacity utilization rate and productivity level, actively guiding enterprises to adopt energy-saving and water-saving, low-carbon transformations such as wood scrap recycling and waste heat utilization, incorporate its low-carbon transformation performance into the platform's credit assessment and rating system, with excellent ones receiving incentives such as preferential order allocations, increased publicity, and expedited certification.

5.3. Platform operation optimization and industry promotion implementation strategy

The platform operation optimization mainly includes two aspects: one is the optimization of the user's experience, and the other is to ensure stable performance of the platform and boost the general working efficiency. Continuously optimize 3D modeling fluidity, algorithm recommendation accuracy, response time of the traceability query, and running stability of the system, but also continuously collect enterprise suggestions and end-user opinions to iterate function modules during operation. The platform builds up and improves the enterprise credit evaluation and low-carbon incentive mechanism to provide positive incentives (such as priority certification, preferential display, and priority order matching for enterprises that have uploaded their data in good faith and achieved excellent low-carbon performance. Thus, keeping control of the platform environment.

At the same time, improve the 7×24 hours customer service and technical support system so that problems found in business and user interaction can be solved quickly and effectively.

After operating experience summary and model optimization, the method was gradually expanded into the surrounding area, and platform function and low-carbon development value were promoted in a variety of ways, such as offline enterprise seminars, exhibitions, trade shows, and seminars or workshops. With the assistance of independent testing laboratories and trade groups, efforts for harmonization and mutual recognition of certifications.

6. Conclusion

In the process of implementing the two carbon goals, the green building materials traceability + low-carbon recognition based on blockchain is an important means to promote the informationization and low-carbon transformation of the wood industry. The Green Materials Cloud" solves the problems faced by consumers and SMEs in terms of material use or business operation through one standard. A secure and reliable traceability system, and an effective cooperative supply chain mode to realize the closed-loop integration of low-carbon design, intelligent production, and transparent delivery. The application can enhance the transparency of green building material information and certification's credibility while promoting effective resource utilization and sustainable carbon emission reduction.

Disclosure statement

The authors declare no conflict of interest.

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