A Reputation-based Carbon Emissions Trading Scheme Enabled by Block Chain

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***Abstract*—The carbon emissions trading scheme plays a significant role in promoting carbon emissions reduction. In this paper, the blockchain technology is applied to the carbon emission trading scheme, and the incentive mechanism of the reputation is added. A reputation-based carbon emission trading scheme (BCR-CETS) enabled by block chain is proposed. Compared with the traditional carbon emission trading scheme, it has the advantages of being safer and more efficient. In addition, case studies prove that BCR-CETS is more conducive to long-term carbon emission reduction.**

Keywords—block chain; reputation; carbon emission reduction; BCR-CETS

I. INTRODUCTION

With the progress of science and technology and the development of society, the emission of greenhouse gases such as carbon dioxide [1] increased year by year. The greenhouse effect caused by greenhouse gases [2] is leading to global warming, endangering human survival. And people are gradually recognizing the importance of reducing carbon emissions. As an important source of carbon emissions, the enterprises should shoulder more responsibility in the process of carbon emissions reduction. In order to achieve better carbon emissions reduction, a carbon emissions trading scheme (CETS) [3] has been formed in European Union. The CETS can be divided into primary market and secondary market. In the primary market, the issuing agencies of the carbon emission permits [4] issue a certain amount of carbon emission permits to enterprises through auctions [5]. Some of them may have redundant carbon emissions permits after covering their emissions. At the same time, some companies may not be able to cover their emissions by their own carbon emission permits. Therefore, the secondary transaction of carbon emission permits will be formed among the enterprises, and the secondary market will be formed.

Block chain technology [6] refers to a combination of data exchange, processing and storage between multiple participants based on modern cryptography [7], distributed consensus protocol [8], peer-to-peer network communication technology [9] and intelligent contract programming language [10]. Enas Al Kawasmi et al. [11] applied the block chain technology to the carbon emission trading scheme. And a bitcoin-based decentralized carbon emissions trading infrastructure model has been designed. Khamila Nurul Khaqqi et al. [12] introduced an incentive value (reputation) in the traditional carbon emission trading scheme to promote carbon emissions reduction. But the calculation method of the reputation is not given in the paper. In this paper, the model proposed by Enas Al Kawasmi et al. is improved, and the reputation is added to the model. At the same time, the calculation formula of reputation value is proposed.

The second part of the paper introduces the architecture and working mechanism of BCR-CETS. The third part introduces the blockchain technology and the calculation method of the reputation. The fourth part proves that the introduction of the reputation will be more beneficial by case study. The fifth part is the conclusion and future work.

II. THE ARCHITECTURE AND WORKING MECHANISM OF BCR-CETS

BCR-CETS is a carbon emission trading scheme based on block chain technology that introduces an incentive value (reputation). It is used in the secondary market of carbon emission trading scheme. Compared with the traditional carbon emission trading scheme, BCR-CETS has a higher transaction efficiency and a better carbon emissions reduction effect.

A. The Architecture of BCR-CETS

Figure 1 shows the architecture of the BCR-CETS, including smart meters, storage device, and the reputation-based trading system and block chain system. Smart meters can detect and record the carbon emissions of the enterprises. Storage device mainly stores some information of users and historical transaction data. Meanwhile, it introduces an incentive value (reputation) in the secondary market of the carbon emission trading system.

The reputation-based trading system includes the market segmentation mechanism and the priority-value-order mechanism. Market segmentation mechanism means that the buyers can only see the sellers that matches with his reputation. The reputation can be divided into three levels: high, middle, and low. Priority-value-order mechanism refers to the sellers sorted by the PV value [12] among the sellers that the buyer can see. The smaller the PV value, the higher the seller's ranking in the buyer's list.

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Block chain system mainly broadcasts the information of carbon emissions permits in the network. As well as subsequent block generation and block verification. And the carbon emissions permits trading information is recorded by using the block chain in the secondary market.

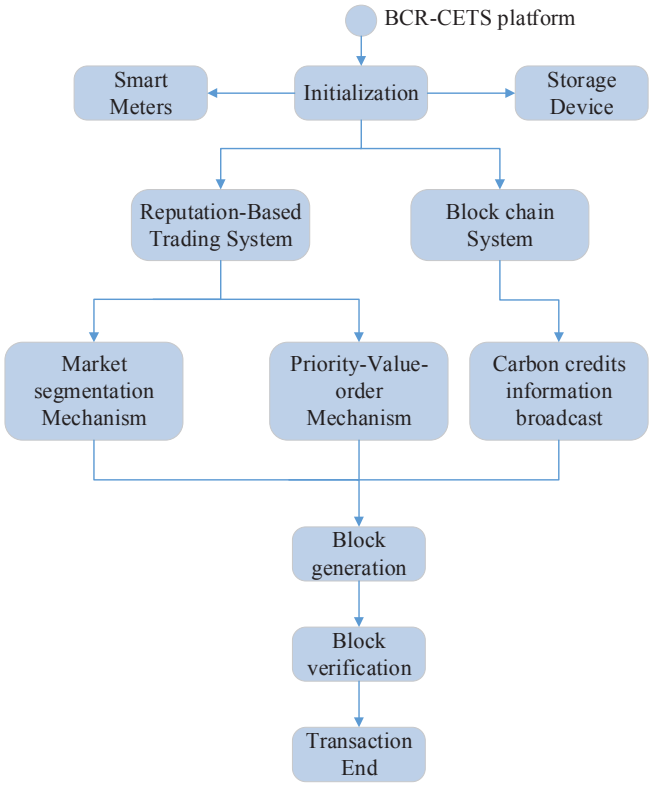

Fig. 1. The architecture of BCR-CETS

B. *The Working Mechanism of BCR-CETS*

There are two main roles in the BCR-CETS designed for the secondary market, buyers and sellers. These two roles are not fixed, but are dynamically changing based on the enterprises' carbon emissions situation. The specific working mechanism of BCR-CETS is as follows.

Step1: Initialize the node information. It mainly includes the initialization of user information, carbon emission permits (size and price etc.).

Step2: Encryption. Using asymmetric encryption algorithms, each node generates its own public and private keys to ensure the privacy and security of the transaction.

Step3: Broadcast. Buyers and sellers broadcast their demand information to the entire network.

Step4: The buyer receives the information. The reputation-based system checks the buyer's reputation information, and the buyer can see the sales information of the part of the carbon emission permits that matches with his reputation according to the market segmentation mechanism.

Step5: According to the priority-value-order mechanism, the sellers are fixedly ordered. Buyers must purchase carbon emission permits in the prescribed order. When the carbon emission permits sold by one seller cannot cover the emissions of the buyers, the buyer can purchase the carbon emission permits of the latter sellers in order. Until the carbon emission permits it purchases can cover its emissions fully.

Step6: The buyer makes a decision on whether to trade. When the seller's bid is higher than the buyer's upper limit, the buyer can give up the transaction. It can obtain carbon emission rights through bidding or carry out technological innovation to achieve the purpose of reducing carbon emissions.

Step7: Determination of transaction information. If the buyer decides to trade, the buyer will digitally sign the transaction agreement. Then a new block containing the transaction information (both participants, size, time etc.) will be generated.

Step8: Block verification. Other nodes verify the new block. When more than 50% of the nodes pass the verification, the new block can be added to the block chain.

Step9: Finish the transaction. When the block containing the transaction information is added to the blockchain, the buyer will receive the required carbon emission permits, the seller will receive the corresponding transaction money, and the transaction ends.

Figure 2 shows the transaction process of BCR-CETS.

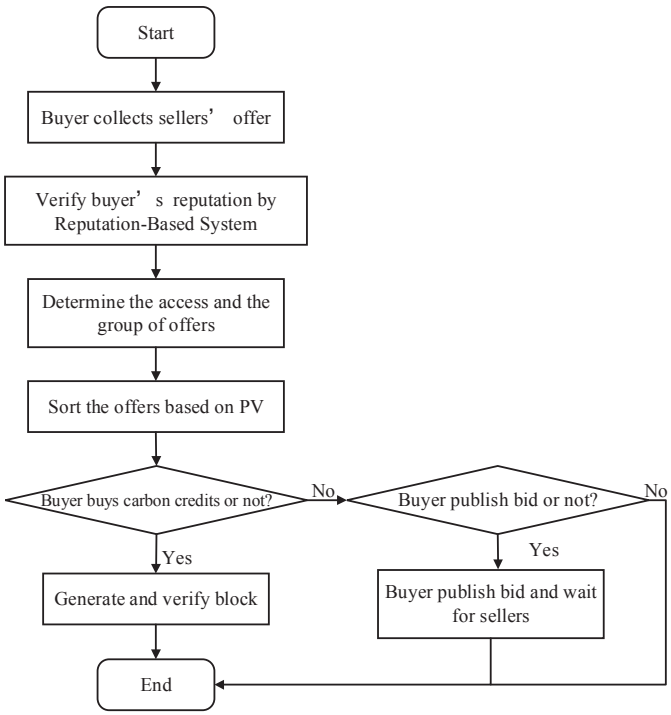

Fig. 2. The trading process of BCR-CETS

III. The Block Chain and Reputation for BCR-CETS

A. The block chain for BCR-CETS

The block chain is essentially a distributed ledger database of peer-to-peer networks. The blockchain itself is actually a series of linked data blocks, and the link pointer is the block header hash value generated by the cryptographic hash algorithm for processing the block header. Each block records a set of tree-like transaction information by using hash algorithms, which ensures that the transaction data in each block cannot be tampered, and the blocks linked in the block chain cannot be tampered at the same time. A schematic diagram of the block chain is shown in Figure 3.

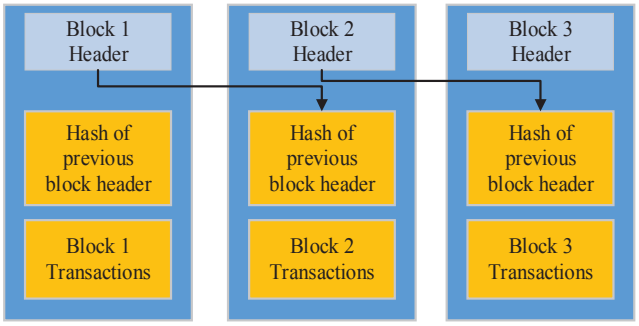

Fig. 3. The architecture of block chain

The block chain uses an asymmetric encryption algorithm (elliptic curve encryption algorithm). In the asymmetric encryption algorithm, there is a pair of mathematically related keys, and one of the keys is used to encrypt the data information, and only the other key can be used to decrypt the information. In the pair of keys, the publicly disclosed key is a public key, and the undisclosed key is a private key. A valid transaction has a digital signature that is valid for the transaction initiator's private key signature, and the signature of the transaction can be verified by using the transaction initiator's public key. The public key can be calculated from the private key by an algorithm, but the private key cannot be pushed out of the public key. Therefore, the blockchain's asymmetric encryption algorithm ensures the privacy and security of carbon emissions permits trading.

A blockchain is a distributed database system that can only be appended and cannot be changed. It is a distributed ledger. In a block chain network, nodes use a consensus algorithm to maintain the consistency of the ledger database in the network. After the buyer and seller complete the transaction, a block containing the transaction information is generated. Other nodes verify the new block. When more than 50% of the nodes are verified, the block can be added to the block chain. The POW mechanism makes it impossible for people who have more than 50% of the network's computing power to tamper with the block. Therefore, the use of blockchain technology for the trading of carbon emission permits is a good guarantee of the authenticity of the transaction. In addition, the transaction information in the block includes the transaction participants, the amount of the carbon emission permits, and the time when the transaction is completed. This is a good way to avoid the double spending problem in the carbon emission trading process.

Finally, decentralization is a prominent feature of the block chain. Applying it to the secondary market for carbon emission permits is quite appropriate. Buyers and sellers can freely trade in BCR-CETS, eliminating the need to report to the intermediary, apply for the intermediary and wait for a response, greatly improving the efficiency of carbon emissions permits trading.

In general, the block chain technology perfectly fits the application of the secondary market for carbon emission trading scheme. It not only ensures the privacy, security and truth of the transaction, but also avoids the double spending problem, and improves the efficiency of the transaction.

B. The reputation value for BCR-CETS

Although the carbon emission trading scheme is established, enterprises need to purchase carbon emission permits before their carbon emissions. However, the emission reduction effect of enterprises and factories is still not very good, and enterprises are more willing to purchase carbon emission permits instead of technological innovations for carbon emission reduction. Therefore, while continuously promoting the use of carbon emission trading scheme, it is still necessary to continuously improve its internal mechanism. This paper introduces an incentive mechanism for the value of reputation in BCR-CETS to promote long-term carbon emissions reduction.

Equation (1) is the calculation formula for the *reputation*. Among them, *REP* is the percentage carbon emissions reduction in this quarter, *RIP* is the percentage investment increasement of technological innovation in in this quarter, and *a* and *b* are two proportional coefficients.

$$reputation = a \cdot REP + b \cdot RIP \tag{1}$$

Equation (2) is the calculation formula for *REP*, where $Emissions_1$ is the carbon emissions of the previous quarter and $Emissions_2$ is the carbon emissions in this quarter.

$$REP = \frac{Emissions_1 - Emissions_2}{Emissions_1} \tag{2}$$

Equation (3) is the calculation formula of *RIP*, in which $Investment_1$ is the investment of technological innovation in the previous quarter, and $Investment_2$ is the investment of technological innovation in this quarter.

$$RIP = \frac{Investment_2 - Investment_1}{Investment_1} \tag{3}$$

The enterprise's reputation will be determined based on the company's carbon emission reduction performance in this quarter. The reputation is updated every quarter. The enterprise's reputation can be divided into three levels: high, middle and low. The different levels can see the different seller's information. Buyers with high reputation can see all the sellers, and buyers with middles can see the top 70% of the most expensive sellers. Buyers with low status can see the top 30% of most expensive sellers. As shown in the Table I.

As can be seen in Table 1, companies with high reputation can get more sellers' information, which means that enterprises with high reputation can purchase carbon emission

rights at a cheaper price. This will promote the company's carbon emission reduction work.

Table I. Market segmentation mechanism

Company	Reputation	Level	Visible Information
Buyer	[0,2]	low	Most expensive 30%
Buyer	(2,4]	middle	Most expensive 70%
Buyer	(4,6]	high	All

IV. Case Study

The carbon emission permits trading in this case was conducted at BCR-CETS. It is intended to demonstrate through case studies that companies with high reputation will receive certain preferential policies when purchasing or selling carbon emission permits which will promote the long-term carbon emission reduction.

According to the actual production in the second quarter, Company A, B, and C all need to purchase 30 carbon emission permits, but the three companies have different reputation. The specific information is shown in Table II.

Table II. The information of buyers

Buyer	Reputation	Level	Visible Information
A	6	high	All
B	3	middle	Most expensive 70%
C	1	low	Most expensive 30%

The seller's information is shown in Table III, and the CEP is the abbreviation of carbon emission permits.

Table III. The information of sellers

Seller	Reputation	Asking price USD/CEP	Size CEP	PV
H	2	1.33	10	0.665
I	3	1.23	7	0.410
J	5	1.30	11	0.260
K	6	1.28	8	0.213
L	1	1.36	12	1.360
M	3	1.32	13	0.440
N	4	1.25	9	0.313
O	1	1.31	8	1.310
P	5	1.24	7	0.248
Q	3	1.29	10	0.430

According to the market segmentation mechanism, Company A can see all sellers' carbon emission permits selling information, Company B can see information of Company L, H, M, O, J, Q, K to sell carbon emission permits, Company C can only see selling information on carbon emission permits of Company L, H, and M.

According to the priority-value-order mechanism, Company A will purchase carbon emission permits in the order of Company K, P, J, and N. Company B will purchase carbon emission permits in the order of Company K, J, Q, and M. Company C will follow Company M, H, L order to purchase carbon emission permits. The purchase scheme, the average transaction price and the holding situation of carbon emission permits of Company A, B, and C after purchase are shown in Table IV, where "+" represents redundancy.

Table IV. Trading scheme for Company A&B&C

Buyer	Sellers	Average price USD/CEP	Balance CEP
A	K&P&J&N	1.271	+15
B	K&J&Q&M	1.300	+12
C	M&H&L	1.337	+5

Company A, B, and C's reputation are declining in turn, Company A purchases 45 carbon emission permits at an average price of 1.271 USD/CEP, with 15 carbon emission permits excess; Company B purchases 42 carbon emission permits at an average price of 1.300 USD/CEP, with 12 carbon emission permits excess. Company C purchases 35 carbon permits at an average price of 1.337 USD/CEP, with 5 carbon emission permits excess. Through the case study, it is not difficult to find that the enterprises with higher reputation will get more benefits when purchasing carbon emission permits.

In addition, from the seller's point of view, the higher the seller's reputation, the more likely it is in the buyer's purchase list. For example, Company A, B, and C now have 15, 12, and 5 carbon emission permits excess respectively. Their identity changes from buyers to sellers. If they sell excess carbon emission permits at the price, which is same with the price they bought, as shown in Table V. Buyers will give priority to the purchase of Company A carbon emission permits, followed by Company B, and finally Company C. Therefore, sellers with higher reputation will also receive preferential policies when they sell excess carbon emission permits.

Table V. The priority order for Company A&B&C

Seller	Reputation	Size CEP	Asking price USD/CEP	PV	Priority order
A	6	15	1.271	0.212	1
B	3	12	1.300	0.433	2
C	1	5	1.337	1.337	3

In general, an enterprise with a higher reputation is more advantageous when purchasing or selling a carbon emission

permits than the enterprise with a lower reputation. Therefore, this incentive mechanism will encourage enterprises to actively invest in carbon emission reduction work. Enterprises will strive to increase the percentage carbon emission reductions and increase investment of technology in carbon emission reduction, which will be more conducive to long-term carbon emission reduction.

V. Conclusion

This paper applies block chain technology to the secondary market of carbon emission trading scheme. The block chain uses an asymmetric encryption algorithm to ensure the privacy and security of user information. Through the POW mechanism, the carbon emission permits transaction is guaranteed to be true and effective. The block contains the time information of the transaction, which is a good way to avoid the double spending problem. In addition, the blockchain is decentralized, which will greatly improve the efficiency of the transaction. In general, the blockchain technology fits well with the application background of the secondary market of carbon emission trading scheme. On this basis, the incentive mechanism of the reputation value is introduced. Case study has proven that the introduction of reputation will be more conducive to long-term carbon emission reduction. At the same time, BCR-CETS still has some shortcomings, such as how to ensure the free trade of the carbon emission permits in the secondary market while introducing the reputation. This is further improvement of the priority-value-order mechanism, which is also the research to be carried out in the future.

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References

[1] N. M. Dowell, P. S. Fennell, N. Shah, and G. C. Maitland, "The role of CO_2 capture and utilization in mitigating climate change," Nature Climate Change, vol. 7, pp. 243-249, April 2017.

[2] G. Althor, J. E. Watson and R. A. Fuller, "Global mismatch between greenhouse gas emissions and the burden of climate change," Sci Rep, vol. 6, p. 20281, February 2016.

[3] R. Martin, M. Muûls and U. J. Wagner, "The Impact of the European Union Emissions Trading Scheme on Regulated Firms: What Is the Evidence after Ten Years?" Review of Environmental Economics & Policy, vol. 10, p. rev016, 2016.

[4] L. Liu, C. Chen, Y. Zhao, and E. Zhao, "China′s carbon-emissions trading: Overview, challenges and future," Renewable and Sustainable Energy Reviews, vol. 49, pp. 254-266, September 2015.

[5] L. Tang, J. Wu, L. Yu, and B. Qin, "Carbon allowance auction design of China's emissions trading scheme: A multi-agent-based approach," Energy Policy, vol. 102, pp. 30-40, 2017.

[6] M. Memon, S. S. Hussain, U. A. Bajwa, and A. Ikhlas, "Blockchain Beyond Bitcoin: Blockchain Technology Challenges and Real-World Applications," in 2018 International Conference on Computing, Electronics & Communications Engineering (iCCECE), 2018, pp. 29-34.

[7] B. Jana, M. Chakraborty, T. Mandal, and M. Kule, "An Overview on Security Issues in Modern Cryptographic Techniques," SSRN Electronic Journal, 2018.

[8] W. Wang, D. T. Hoang, Z. Xiong, D. Niyato, P. Wang, Y. Wen, and P. Hu, "A Survey on Consensus Mechanisms and Mining Strategy Management in Blockchain Networks," IEEE Access, vol. 7, pp. 22328-22370, July 2019.

[9] C. Xu, S. Jia, L. Zhong, and G. Muntean, "Socially aware mobile peer-to-peer communications for community multimedia streaming services," IEEE Communications Magazine, 53(10): 150-156, October 2015.

[10] S. Wang, L. Ouyang, Y. Yuan, X. Ni, X. Han, and F. Wang, "Blockchain-Enabled Smart Contracts: Architecture, Applications, and Future Trends," IEEE Transactions on Systems, Man, and Cybernetics: Systems, pp. 1-12, February 2019.

[11] E. A. Kawasmi, E. Arnautovic, D. Svetinovic, E. A. Kawasmi, E. Arnautovic, and D. Svetinovic, "Bitcoin-Based Decentralized Carbon Emissions Trading Infrastructure Model," Systems Engineering, vol. 18, pp. 115-130, March 2015.

[12] K. N. Khaqqi, J. J. Sikorski, K. Hadinoto, and M. Kraft, "Incorporating seller/buyer reputation-based system in blockchain-enabled emission trading application," Applied Energy, vol. 209, pp. 8-19, January 2018.