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ORIGINAL PAPER

Comparative analysis of the international carbon verification policies and systems

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Abstract Carbon verification, which can guarantee the reliability and credibility of greenhouse gas (GHG) emission data, is the most important part of the daily operations of the carbon emission right trading system. Many international institutions, countries and regions have conducted research on and have practiced carbon verification policies and systems. Through comparative analysis of the international carbon verification policies and systems, they can provide experience for Chinese unified national carbon market to start supporting carbon verification. The paper study concludes that (1) carbon verification systems developed by international institutions focus on the scientific level of verification methods; (2) carbon verification policies and systems issued by important countries and regions draw on International Standardization Organization (ISO)14064 standards based on their national conditions and focus on the scientific level and reasonableness of verification methods; (3) major international experience includes complete verification policies and systems, strict standard verification procedures, diversified verification forms and a focus on key emission sources. Based on the differences in China's carbon emissions characteristics caused by unbalanced regional economic development and the conditions of carbon verification in seven pilot carbon trading areas, this thesis proposes the following suggestions: pushing forward the establishment of carbon verification policies and systems by accelerating legislation on climate changes; facilitating carbon verification in a coordinated manner; regulating key GHG emission sources; establishing and improving supervision on carbon verification; and intensifying international exchanges and cooperation.

Keywords Carbon verification · Greenhouse gas emissions · International institutions · Policies

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1 Introduction

Coping with climate change and promoting a low-carbon economy have become global preoccupations. Carbon trading as an effective market tool for reducing carbon emissions has originated from the Kyoto Protocol. Bali Action Plan was approved in the COP13 of UNFCCC, proposed measureable, reportable and verifiable (MRV; UNFCCC 2007). MRV remains an important issue as mitigation efforts (Tyler et al. 2013). So require the establishment of MRV system (Pedro et al. 2000; Breidenich and Bodansky 2009; Fransen 2009; Winkler et al. 2008) and coordination by government (Anya et al. 2014). With the development of carbon trading, the importance of carbon verification—the most technically complex step in carbon trading—is rising (Duan and Pang 2013). Carbon verification refers to a process in which effective carbon verification is performed on the actual emission amounts of enterprises using standard GHG emission detection, reporting and verification systems. Verified information is submitted to supervising organizations to guarantee the reliability and credibility of GHG emission data (Edward and Jayant 1999). Carbon verification is the most important part of the daily operations of the carbon emission rights trading system, which lead significantly to the carbon price fluctuation (Jia et al. 2016). Various countries have launched carbon verification policies and systems to safeguard the performance of carbon verification. The importance of carbon verification policies and systems may be encapsulated in the following three points. First, carbon verification can be utilized for verifying international carbon emission reduction. As national sovereignty is involved, an independent third-party verification institution is usually needed to verify the carbon emission reduction actions (and supporting actions) of respective parties according to commonly recognized rules, so that a foundation of mutual trust foundation can be laid. Second, by effectively verifying the actual emission amounts of emitting entities by third-party verification institutions, the actual emission reduction amount can be evaluated objectively, fairness and openness of the carbon emission trading market can be ensured and regulation of orders of the carbon emission trading market can be facilitated. Third, by supervising third-party verification institutions, governments can effectively reduce supervision cost, improve supervision efficiency and enhance supervision transparency and credibility.

Many international institutions and countries value the role of carbon verification in carbon emission right trading highly and, therefore, have conducted research on and practiced carbon verification policies and systems. Major international institutions carrying out such research include the Inter-governmental Panel on Climate Change (IPCC), the International Standardization Organization (ISO), the World Business Council for Sustainable Development (WBCSD) of the United Nations and the World Resource Institute (WRI). The carbon verification standards of the IPCC are applied mainly to the Clean Development Mechanism (CDM). The ISO carries out verification work for GHG emissions at organizational levels and project levels according to the ISO14064 standards. The WBCSD/WRI has explained the importance of carbon verification in the Greenhouse Gas Verification Systems: Verification and Reporting Rules for Enterprises (Revised Edition). Important countries and regions include the European Union (EU), the USA, New Zealand, Australia, Japan, South Korea and India, among others (Zheng 2014). The EU, the USA, Australia and Japan have launched representative carbon verification policies and systems. The carbon trading market in the EU has been in operation for a long time, with wide coverage and well-established supervision systems. The USA does not have a nationwide carbon trading system, but some states and enterprises voluntarily form various regional

carbon trading markets. The Measurement, Reporting and Verification (MRV) System of Australia has been operational for many years, and its carbon verification policies and systems are quite sound. Japan, taking Tokyo as a key area, has passed modified environment protection regulations for Tokyo to guarantee the health and safety of the people there and has also identified large organizations as entities responsible for reducing GHG emissions.

In China, Beijing, Tianjin, Shanghai, Chongqing in southwest China, Hubei Province in central China, Guangdong Province in south China (excluding Shenzhen) and Shenzhen were selected as pilot areas for carrying out carbon emission right trading in 2011. The selected pilot cities and provinces have taken regional differences into account and have wide representation. The central government of China and the aforementioned pilot cities and provinces have successively launched carbon verification policies and systems. After development for 4 years and more, the carbon verification policies and systems launched by the central government of China and the pilot cities and provinces are still in the process of improving. All these carbon verification policies and systems have given rise to strict requirements for third-party verification institutions. Specifically, competent third-party verification institutions should possess the required qualifications for GHG detection, calculation and measurement, for evaluating related reports submitted by enterprises and for formulating the strict procedures required for carbon verification, as well as being responsible for their actions. The formulation of carbon emission verification regulations, standards and work rules has already been put on the agenda, and related research is being pushed forward. However, establishing a nationwide carbon emission right trading market in China in 2017 is challenging. The progress of improving current carbon verification policies and systems lags behind development requirements. How to effectively guide third-party verification institutions to expand their scales, to improve their service quality, to deploy their personnel rationally and to improve their service capabilities, and how to effectively guide governments to establish and improve supervision systems for third-party verification institutions using sound carbon verification policies and systems have become urgent and difficult problems. This paper, by investigating and studying international carbon verification policies and systems, has drawn conclusions from useful international experiences. In this light, it makes some policy suggestions for China in accordance with the country's particular conditions in order to facilitate the study and practice of carbon verification policies and systems in China. The content is mainly divided into four parts. The first part expounds the present situation of the international carbon verification policies and systems. The second part is a comparative analysis of the international carbon verification policies and systems. The third part summarizes the conclusion. The fourth part puts forward suggestions on the policies and systems of carbon verification in china.

2 Current situations of international carbon verification policies and systems

2.1 International institutions

2.1.1 IPCC

The IPCC is a major science and technology consulting institution for the United Nations Framework Convention on Climate Change (UNFCCC) and the annual United Nations

Climate Conference (UNCC). The Kyoto Protocol (KP) signed at the UNCC held in Kyoto, Japan in 1997 endowed a product attribute to carbon emission rights for the first time and established three flexible cooperation mechanisms for GHG emission reduction (UNFCCC 1997). One of the three mechanisms is the CDM, which is a trading mechanism by which the contracting parties in Appendix 1 (or developed countries) are allowed to fulfill their emission reduction commitments by purchasing the emission reduction amount of GHG emission reduction projects of the countries not listed in Appendix 1 (or developing countries). To ensure scientific and normative implementation of CDM projects and emission reduction amount trading, the CDM Executive Board of the UNFCCC (UNFCCC-EB) has formulated a series of strict regulations and procedures for the related activities in the life cycle of a CDM project. Among these regulations and procedures, carbon verification is the most important. The UNFCCC-EB provides that a carbon emission reduction project cannot be traded in the international carbon emission trading market without undergoing a normal carbon emission verification procedure. Verification of the carbon emission reduction amount of a registered CDM project should be performed by a third-party verification institution whose qualifications are approved by the UNFCCC-EB and which is recorded by the same. After the project boundaries, the data sources, the quantization methods and the carbon emission reduction amount of a registered CDM project are verified, and a written guarantee is presented, which can prove that the project has achieved a certain amount of GHG emission reduction.

2.1.2 ISO

The ISO is a very important organization in the field of international standardization. As an international organization closely related to responses to climate changes, the fifth working group of the Technology Sub-committee on Climate Change, ISO TC207, develops the ISO 14000 series standards, which specify the internationally prevailing data compilation, detection and quantization methods and verification regulations for GHG emissions through organizations and projects. These series standards can improve the consistency, transparency and reliability of quantization results of GHG emissions and can facilitate the verification and trading of GHG emission reduction amounts of organizations and projects. The part ISO14064-3 (GHG, Part III: Rules and Guidelines for Assessing and Verifying Declarations on GHG) presents the verification standards. The part ISO14064-3 describes the verification principles and requirements for GHG emission list of organizations and projects, regulates the GHG emission verification procedures, as well as specifying the verification plan, the verification procedures, the verification discoveries and the verification declaration, etc. The part ISO14065 (GHG, Requirements for Accepting or Recognizing in Other Forms GHG Verification and Confirmation Institutions) specifies the content to be recognized by third-party verification institutions. That is, ISO14065 specifies the requirements and guidelines for the quality management, reporting and internal auditing of the lists for verifying GHG emissions (Chen 2011).

2.1.3 WBCSD/WRI

The Greenhouse Gas Protocol Advocacy Organization is a platform established by various stakeholders including companies, non-governmental organizations (NGOs), governments and other organizations in response to the call of the WRI and the WBCSD, with the aim of controlling GHG emissions. The purposes of this organization include formulating internationally recognized Enterprise GHG accounting and reporting rules, and promoting the

application of such rules based on the platform. The first edition of *Greenhouse Gas Accounting Systems: Enterprise Accounting and Reporting Standards* completed by this organization were published in September, 2001. The book was modified in 2004, with the intention of providing standard guidance for enterprises and other types of organization in formulating GHG lists. The book also illustrates the necessity for verification after explaining the accounting methods for enterprises. In addition, it states that the main aim of verification is to guide how to assess the accuracy and completeness of GHG emission lists of enterprises fairly and objectively and how to ensure the normalization of GHG data sources and the quantizing process. The book also emphasizes the importance of the key steps of the verification procedure to the process and results when enterprises prepare the accounting data and formulate the GHG emission list. The book also specifies that the assessment of risks of possible deviations between the GHG emission list of enterprises and the actual conditions should be performed. "Deviation" refers to a degree of difference between the GHG emission list of enterprises obtained according to this book and the GHG emission data of enterprises obtained according to other related standards and methods (Chen 2011).

2.2 Important countries and regions

2.2.1 The EU

The European Commission issued a book entitled *Greenhouse Gas Emissions Rights Trading in the European Union* in 2000. This book suggests implementing an "upper limit-trading" mechanism in the EU, and suggests that marketized measures should be employed to reduce the cost of achieving the objective of reducing emissions by 8 % in the first commitment period (from 2008 to 2012) specified in the KP. The book explicitly required that the EU ETS trading mechanisms, application of emission licenses, registration of carbon emission right trading, settlement and transfer of carbon emission quota by enterprises should be subject to verification of the monitoring methods and reporting content of the carbon emission data of enterprises. To ensure the fairness and accuracy of carbon emission data for carbon emission right trading, the EU requires that the verification work and the verification institutions must follow the provisions of the Regulations for the European Union Carbon Emission Trading System Verification and Verification Institutions. Appendix V of the Directive 2003/87/EC and the Commission Decision 2007/589/EC specify the systems for carbon emission detection, reporting and verification, specifying the following: the reliability, credibility and accuracy of an emission detecting system of an apparatus, and of data and information related to carbon emission amounts reported by enterprises should be verified; only after meeting the above condition will the carbon emission amounts be verified as valid; and the verification personnel should consider whether the apparatus has been registered with the ecology management and auditing system of the EU. Afterward, the Accreditation and Verification Regulation Explanatory Guidance further specifies the application of verification methods, the execution of the verification procedures and the drafting of verification reports.

2.2.2 The USA

The USA has compulsory GHG emission list reporting principles (GHGRP), but it does not issue compulsory laws and regulations for GHG emission reduction at the federal level. Some states or enterprises in the USA have initiated carbon trading voluntarily. Such

initiatives include the Regional GHG Emission Reduction Initiative (RGGI) in the northeastern ten states, the West Climate Initiative (WCI), the Middle GHG Emission Reduction Agreement (MGGRA) and the California State Carbon Trading Initiative. Verification as an important step in carbon trading also deserves due attention (Certification and Accreditation Institute of China Certification and Accreditation Administration 2014).

1. GHGRP

The GHGRP requires enterprises to entrust third-party verification institutions with the verification of their GHG emission list reports and to submit the same to the US Environment Protection Agency (U.S. EPA). The US EPA verifies the related data, the quantizing process of the submitted carbon verification reports of enterprises online, the completeness and accuracy of the reports as well as the consistency of additional information online and periodically inspects GHG emission facilities of enterprises. At the same time, the U.S. EPA also verifies the authorization certificates and qualifications of third-party verification institutions.

2. Chicago Climate Exchange (CCX)

The CCX has formulated a sound carbon emission reduction verification system and established a standard third-party verification system in order to carry out carbon trading. For verification work, the CCX strictly specifies the verification methods, the verification plan, the execution of verification and verification suggestions etc. For verification institutions, the CCX certifies the name list of third-party verification institutions and publishes the same for principals to select. If a third-party verification institution selected by a principal is not included in the name list, the principal shall apply to the CCX. Only after certification and adding of the third-party verification institution into the name list, can verification work be performed by that third-party verification institution (U.S. CCX 2011).

3. WCI

The WCI specifies that carbon verification shall be conducted according to the ISO14064-3 standards and suggests compulsory execution of carbon verification through legislation. The WCI requires verification teams to design scientific verification procedures, decompose verification steps reasonably, independently verify GHG emission results annually and periodically, as well as prevent substantial mistakes under the requirements of the WCI. At the same time, the WCI also requires that verification institutions should pass certification of ISO14065 and ISO17011 standards.

4. California State Carbon Trading Initiative

The verification policies of the California State Carbon Trading Initiative include the Regulation for the Mandatory Reporting of Greenhouse Gas Emissions. This Regulation exhaustively specifies the requirements on verification preparation, verification reports, verification services and verifying personnel. Specifically, the objectivity and independence of verification institutions and verification personnel should be determined; and if verification work is to be carried out within acceptable scopes, a verification notification should be submitted to the California Air Resource Board (ARB). The verification services include verification plans, execution of the verification, the sampling schemes, verification discoveries and verification declarations (U.S. EPA 2015).

2.2.3 Australia

The Ministry for Climate Changes and Energy Efficiency of the Australian government has issued the National Greenhouse Gas and Energy Reporting (Verification) Decision and the National Greenhouse Gas and Energy Report Verification Guidelines. Verification of GHG emission and energy consumption is a key monitoring measure provided by the National Greenhouse Gas and Energy Reporting Act of Australia (NGER 2014). According to this measure, verification and authentication for the items required by the National Greenhouse Gas and Energy Reporting Act should be provided to the GHG emission data verification personnel or verification institutions. Australia has acquired more than 20 years of experience in the MRV system (or the National Greenhouse Gas Emission List Pooling System under the management of the Australian federal government) and has experienced the following five milestone events. (1) The National Greenhouse Gas Emission List Pooling System was established in 1991. (2) The MRV system was launched for the field relating to land resources in 1999. (3) The Australian Greenhouse Gas Emission Information System was established in 2004. (4) The National Greenhouse Gas and Energy Reporting System was established in 2007. (5) The National Greenhouse Gas and Energy Reporting Act was passed in 2007. According to this Act, it is compulsory for an enterprise exceeding the GHG emission quota to provide an enterprise GHG emission list report and a verification report and to publish its GHG emission data. The Carbon Pricing Mechanism (CPM) was established in 2012, which further improved the carbon trading system.

2.2.4 Japan

The carbon trading system in Japan experienced three stages including the Voluntary Environmental Protection Action Initiative in 1997, the trial Japan Voluntary Emission Reduction Trading System (JVETS) and local compulsory control and trading system for total GHG emission amount in 2010. The development of the carbon trading system in Japan benefits from voluntary actions of emitting organizations, and the verification work is performed by third-party verification institutions determined by management institutions. To ensure the accuracy and independence of verification results, third-party verification institutions are required to have the corresponding qualifications and should have no interest in the GHG emitting organizations. The carbon trading system in Japan is built mainly by Tokyo and the JVETS. The total amount "upper limit-trading" system of Tokyo is the first total carbon emission amount trading system at city level in the world and is based mainly on the Verification Guidelines for Fulfilling the Responsibility of Reducing the Total Greenhouse Gas Emission Amount and Fulfilling the Trading System Requirements; Guidelines for Registration Procedures for Application of Verification Institutions for regulating GHG emission verification work and verification institutions. The JVETS is the earliest experimental system for carbon emission right trading, which uses the total amount trading method and mainly covers industrial fields. The Emission Amount Verification Guidelines of Japan Voluntary Emission Reduction Trading System, formulated with reference to the ISO14064-3 and ISO14065 standards, regulates the verification work, verification institutions and verification personnel for carbon trading in Japan (Teng and Feng 2012).

3 Comparison and analysis of international carbon verification policies and systems

3.1 Main carbon verification systems of international institutions

3.1.1 Important content of carbon verification systems

Main carbon verification systems of international institutions include CDM Guidelines, ISO14064 series standards and Greenhouse Gas Accounting Systems: Enterprise Accounting and Reporting Standards, whose important content is listed in Table 1.

Table 1 Table of main carbon verification systems of international institutions

Name of system	CDM Guidelines	ISO14064 series standards	Greenhouse gas accounting systems: enterprise accounting and reporting standards
Issuing institution(s)	IPCC	ISO	WBCSD/WRI
Verification purposes	To verify GHG emission reduction quantity and provide verification results trusted by both trading parties	To ensure the completeness, accuracy, consistency, transparency and no substantial deviation of GHG emission declarations of organization or projects	To enhance the credibility of GHG accounting reports and provides reference to related investment decisions and objectives
Verification principles	Transparency, conservatism, qualification, fairness and comparability	Independence, ethical conducts, fair expression, professionalism and substantiality	Objectivity, transparency, systematic completeness, verifiability and substantiality
Verification methodologies	Specified methodologies	ISO14064-3	Content to be verified according to the GHG accounting system
Verification techniques	(1) Preliminary verification: verifying if the project is implemented according to the plans and monitoring if the system is operating effectively (2) Periodical verification: periodically and independently carrying out re-verification and post-confirmation	Specifying the guarantee level, purposes, principles and ranges of the verification; selecting the verification procedures; evaluating GHG information systems and control thereof; evaluating GHG information; verifying declarations; verifying statements; verifying records and discovering after verification	Selecting verification personnel, setting verification parameters, designating verification period, performing field inspection, performing data verification and issuing verification reports
Verification manners	Verification by third-party verification institutions	Verification by third-party verification institutions and enterprises themselves	Verification by third-party verification institutions and enterprises themselves
Applicable ranges	International projects	Organizations (enterprises) and projects	Organizations (enterprises)

3.1.2 Comparison of carbon verification systems

As shown in Table 1, the comparison is carried out in terms of the aspects of verification purposes, verification principles, verification methodologies, verification techniques, verification manners and applicable ranges.

When analyzed from the aspect of verification purposes, the following results are obtained. The CDM Guideline emphasizes increasing credibility for both the buyer and the seller; the ISO14064 series standards on reliability of GHG declarations; the Greenhouse Gas Accounting Systems: Enterprise Accounting and Reporting Standards on increasing credibility in order to provide reference for decision making or guide internal improvement. Both the CDM Guidelines and the Greenhouse Gas Accounting Systems: Enterprise Accounting and Reporting Standards require an increase in credibility, but the key points of emphasis are different. The CDM Guidelines focus on providing services to both the buyer and the seller by third-party verification institutions, while the Greenhouse Gas Accounting Systems: Enterprise Accounting and Reporting Standards indicate that the third-party verification institution and internal verification have equal requirements regarding credibility.

When analyzed from the aspect of verification principles, the following results are obtained. All three verification systems emphasize objectivity, fairness and transparency, meeting the main function requirement of verification. The CDM Guidelines also emphasize qualification, conservatism and comparability, indicating that the corresponding qualifications of the verification institution are required, the main requirements for the verification process are raised, and accuracy of the carbon emission amount is required. The ISO14064 series standards and the Greenhouse Gas Accounting Systems: Enterprise Accounting and Reporting Standards include the principle of substantiality. The ISO14064 series standards require that substantiality should be agreed upon before verification is performed, while the Greenhouse Gas Accounting Systems: Enterprise Accounting and Reporting Standards allows for substantiality to be adjusted during the verification process and in the verification report. The ISO14064 series standards and the Greenhouse Gas Accounting Systems: Enterprise Accounting and Reporting Standards also emphasize ethical conduct and verifiability.

When analyzed from the aspect of verification methodologies, the following results are obtained. The verification methodologies employed by the CDM Guidelines are formulated and revised by the UN CDM-EB, including the approval new verification methodologies relating to the reference lines, monitoring plans and project boundaries. The ISO14064 series standards clearly specify the principles and requirements for GHG emission list verification and GHG item approval or verification, explain the GHG approval and verification process and specify the content thereof. The Greenhouse Gas Accounting Systems: Enterprise Accounting and Reporting Standards emphasize internal verification of enterprises. Only one chapter of this book discusses the verification process and focuses mainly on transparency. Generally, the methodologies employed in this book are not complete, but may be used as reference materials for third-party verification institutions.

When analyzed from the aspect of verification techniques, the following results can be obtained. The CDM Guidelines are divided into two stages. The ISO14064 series standards emphasize the whole flowchart. The Greenhouse Gas Accounting Systems: Enterprise Accounting and Reporting Standards emphasized entails such as the verification ranges and verification details. Each stage of the CDM Guidelines focuses on different items, with the first stage focusing on the execution of the plan, and the second stage on the control of the

execution. The ISO14064 series standards mention that while clearly identifying the guarantee level, purposes, principles and ranges of the verification, the GHG report and the steps should be verified. The Greenhouse Gas Accounting Systems: Enterprise Accounting and Reporting Standards consider all the nodes, and specify the verification parameters, time etc.

When analyzed from the aspect of verification manners, the following results are obtained. The CDM Guidelines require that verification of a CDM project should be performed by a designated organization or entity (DOE). The ISO14064 series standards specify the qualifications, capabilities of the verification personnel, deployment of the verification personnel, rights and obligations between the verification institution and the principal, and the normal verification process, as well as mentioning that internal verification may refer to external verification or verification by third-party verification institutions. According to the Greenhouse Gas Accounting Systems: Enterprise Accounting and Reporting Standards, the verification work is mainly performed by a third-party verification institution entrusted to do this work by a company, internal personnel of the company are allocated for internal verification independent from the GHG accounting and reporting verification done by the third-party verification institution, and the internal verification should follow similar procedures and steps to those used by the third-party verification institution.

When analyzed from the aspect of applicable ranges, the following results are obtained. The CDM Guidelines are applied to carbon trading projects between the contracting parties in the Appendix 1 (or developed countries) and the countries not listed in Appendix 1 (or developing countries) according to the KP. The ISO14064 series standards are used for calculating and verifying GHG emission amounts for organizations (enterprises) or projects. The Greenhouse Gas Accounting Systems: Enterprise Accounting and Reporting Standards provide corresponding principles and guidance for enterprises and other types of organization formulating GHG lists.

3.2 Important countries and regions

3.2.1 Key content of carbon verification polices and systems

Important countries and regions such as the EU, the USA (California and Chicago), Australia and Japan (Tokyo and JVETS) have issued strict requirements for carbon verification based on their national conditions while drawing on the ISO14064 series standards. For details, please refer to Table 2.

3.2.2 Comparison of carbon verification polices and systems

When analyzed from the aspect of the purposes of the carbon verification polices and systems, the following results can be obtained. Trueness and accuracy of verification reports are ensured by each of the important countries and regions by employing verification institutions and verification personnel to perform verification and establishing standard procedures, so that good order of carbon trading can be maintained. Although the focal points are slightly different for the EU and Australia, the carbon trading systems are relatively complete. Carbon trading systems are established in the USA with California and Chicago as models and in Japan with Tokyo and JVETS as models on a compulsory basis and a voluntary basis, respectively. Compared with international institutions, the legal

Table 2 Major carbon verification polices and systems of important countries and regions

Country/region	The EU	The USA		Australia	Japan	
		California	Chicago		Tokyo	JVETS
Names of policies and systems	The Accreditation and Verification Regulation	Regulation for the Mandatory Reporting of Greenhouse Gas Emissions; Greenhouse Gas Reporting Program Regulation for the Mandatory Reporting of Greenhouse Gas Emissions	CCX Offset Project Protocol	National Greenhouse and Energy Reporting Regulations; Audit Determination Handbook	Verification Guidelines for Fulfilling the Responsibility of Reducing the Total Greenhouse Gas Emission Amount and Fulfilling the Trading System Requirements; Guidelines for Registration Procedures for Application of Verification Institutions	Emission Amount Verification Guidelines of Japan Voluntary Emission Reduction Trading System
Verification purposes	To ensure the trueness and accuracy of GHG emission data in the report	To establish compulsory GHG emission accounting, reporting and verification rules to meet supervision requirements	To ensure the legitimacy of GHG emission accounting and verification and to ensure the consistency of the report	To guide verification work of verification institutions and verification personnel	To guide verification work, authenticate verification procedures, and regulate confirmation methods and judgment standards	To meet the verification requirement of realizing voluntary emission reduction targets
Verification principles	Reliability, credibility and accuracy of data and information	Transparency, objectivity, accuracy and trueness of data	Legitimacy, trueness, operability and accuracy of the project	Independence, objectivity and transparency	Ensuring the correctness and credibility of GHG quantized emission results and the fairness of "fulfilling the obligations of reducing GHG emission" and "GHG emission amount trading"	
Verification techniques	Avoiding conflict of interests, assessing capabilities of personnel, establishing a verification team, identifying risks, making verification plans, guaranteeing completeness and validity of the verification and proposing improvement suggestions					

Table 2 continued

Country/region	The EU	The USA		Australia	Japan	
		California	Chicago		Tokyo	JVETS
Verification manners	Declarations on the trueness of the report, and independent third-party verification	Declarations on the trueness of the report, verification by supervising institutions and independent third-party verification	Declarations on the trueness of the report, and independent third-party verification	Declarations on the trueness of the report, verification by supervising institutions and independent third-party verification	Declarations on the trueness of the report, and independent third-party verification	Declarations on the trueness of the report, and independent third-party verification
Applicable ranges	Enterprises, facilities and the aviation industry	Facilities, suppliers and physical enterprises	Enterprises and projects	Enterprises and facilities	Commercial facilities and factories	Industrial enterprises and projects

bases of the important countries and regions are sound and complete, which is closely related to the administrative jurisdiction rights of these countries.

When analyzed from the aspect of the principles of the carbon verification polices and systems, the following results are obtained. The important countries and regions perform verification to ensure the objectivity, accuracy and trueness of carbon trading. The major verification principles, particularly objectivity, of the important countries and regions are basically the same as those of international institutions. The slight difference between the two is that international institutions focus on transparency and openness of carbon trading data, while the important countries and regions focus on trueness and operability and have more prudent requirements. This difference indicates that national administration has its own features and advantages for carbon trading, particularly compulsory carbon trading.

When analyzed from the aspect of the verification techniques of the carbon verification policies and systems, the following results are obtained. The important countries and regions divide the verification process into the following steps: avoiding conflict of interests, assessing capabilities of the verification team, identifying risks, making verification plans, guaranteeing the completeness and validity of the verification, making suggestions for improvement and emphasizing scientific and standard verification techniques. The verification techniques used by the important countries and regions are basically the same as those used by international institutions. This indicates that the carbon verification policies and systems of the important countries and regions have drawn on international experience, but the important countries and regions have more prudent and detailed requirements, which is closely related to the fact that the carbon trading market is mainly promoted by the respective countries and regions.

When analyzed from the aspect of the verification manners of the carbon verification polices and systems, the following results can be obtained. All six verification systems use both internal and external verification and employ declarations as to the trueness of the reports and independent third-party verification. In addition, the USA and Australia also require supervising institutions to perform verification. As the number of companies and other reporting entities covered by the GHG reporting mechanisms is quite large, supervising institutions and third-party verification institutions alone are not sufficient. Therefore, verification is usually performed by sampling. The most commonly used method is external verification of the trueness of the reports as well as declarations on the trueness of the reports. Compared with international institutions, the verification methods of the important countries and regions are diverse, as declarations by enterprises are added. Even online verification is adopted by some important countries and regions.

When analyzed from the aspect of the applicable ranges of the carbon verification polices and systems, the following results are obtained. Each of the important countries and regions carry out verification for enterprises. Compulsory carbon trading has reached the facility level, and voluntary carbon trading covers organizational activities. The EU even includes the aviation industry in its carbon trading system. Compared with international institutions, the verification requirements of the important countries and regions are more detailed. For example, carbon emission verification required by the important countries and regions includes carbon emission verification of facilities, in particular commercial ones, while carbon emission verification required by international institutions only includes general enterprises or organizations.

4 Conclusions

The development of verification systems by international institutions focuses on scientific verification methods. And important countries and regions issue their verification policies and systems based on their national conditions while drawing on the ISO14064 series standards, as well as focusing on scientific verification methods or emphasizing operability. Their experiences may be summarized in the following four points, based on the above comparative analysis.

1. Sound verification policies and systems

The important countries and regions have issued related laws and regulations to provide legal bases for GHG emission accounting, monitoring, reporting, third-party verification institutions and verification reports. For example, the EU has launched many carbon trading regulations, such as the Directive 2003/87/EC, the Directive 2009/29/EC, Regulation No. 2216/2004 (EU Carbon Market Quota Registration Regulations), and Monitoring and Reporting Guidelines MRG2004 and MRG2007. The Australian government has issued the National GHG and Energy Reporting Act, the National Greenhouse Gas and Energy Reporting (Verification) Decision, the National Greenhouse Gas and Energy Report Verification Guidelines, etc.

2. Strict and standard verification procedures

The important countries and regions have strict requirements for the verification procedures, which are usually divided into four stages, namely the preparation stage, the planning stage, the execution stage and the reporting stage. Each stage focuses on different items. The preparation stage focuses on establishment of the verification team, in which the verification team leader and other team members should be selected objectively and responsibly. The planning stage focuses on making the verification plan, in which the conditions of enterprises should be identified, risks identified and the verification solution worked out. The execution stage focuses on performance according to the verification steps, in which the compliance of verification and accounting should be ensured and problems should be identified. The reporting stage focuses on verifying declarations, in which the problems should be addressed to meet verification requirements.

3. Diversified Verification Forms

The verification forms adopted in the important countries and regions may be divided into the following types: a declaration on the trueness of the report, second-party verification performed by supervising institutions, third-party verification performed by qualified third-party verification institutions and internal verification by enterprises. The second-party and third-party verifications can be classified as external verification, which mainly aims to ensure the quality of data in the GHG accounting reports of enterprises and perform compliance authentication for the collection and management of the related data. The main aim of internal verification by enterprises is to improve the GHG emission accounting and reporting system by enterprises themselves, to identify problems, and to avoid and correct non-compliant items. Accuracy and completeness of data in the GHG accounting reports of enterprises can be ensured by both external and internal verification.

4. Focusing on key emission sources

For compulsory carbon trading requiring high accuracy and credibility, the important countries and regions specify in detail the applicable range, which can reach facility level and provide key attention points for verification. By focusing on key GHG emission

sources, key emission sources such as the high energy-consuming facilities, production techniques and processes can be identified clearly and accurately, and major GHG emission rings can be identified, so that important references for collection and processing of GHG emission data in the steps of document evaluation, field inspection and so forth can be provided. For example, the EU has listed more than 25,000 facilities as key emission sources.

5 Suggestions for carbon verification policies and systems in China

Developed countries and regions represented by the EU, the USA and Japan establish carbon trading markets based on a relatively slower economic growth rate, a basically stable industry structure and a relatively slower growth rate of total carbon emission quantity; therefore, so it is relatively easier for them to control the total carbon emission quantity. China, which is in the process of industrialization and urbanization, enjoys a relatively higher economic growth rate but faces the challenge of substantially increased carbon emissions. In particular, coal takes up an important position in China's energy structure (Li et al. 2015). And Coal not only consumes large amount and low efficiency (Li et al. 2016). So its carbon emission reduction situation is severe. Chinese government vigorously improves the policy instruments to promote the construction of carbon trading (Gu et al. 2010), which be to mitigate climate change action oriented.

Carbon trading is an important means of carbon emission reduction. With a nationwide carbon trading market to be established, establishing sound carbon verification systems in China is a major step in regulating the nationwide carbon trading market. Considering China's carbon emissions characteristic differences caused by unbalanced regional economic development and the implementation condition of carbon verification in seven pilot carbon trading areas (Chen 2012; Dai et al. 2014), this paper makes the following five suggestions.

1. Pushing forward the establishment of carbon verification policies and systems by accelerating legislation on climate change

China should accelerate legislation on climate changes and promote the launching of rules and systems related to carbon trading in order to provide legal support for starting the nationwide carbon trading market and the policies and systems followed. The systems of laws and regulations related to GHG emission reduction, such as the Law on Energy Conservation of China, should be improved to lay a foundation for comprehensively pushing forward GHG emission reduction. Research on and formulation of carbon verification policies and systems suitable for China's particular conditions should be stepped up. Carbon verification procedures should be regulated by formulating related rules and implementation guidelines, such as the GHG Emission Verification Guidelines. Work procedures for third-party verification institutions should be regulated.

2. Facilitating carbon verification in a coordinated manner

The establishment of a nationwide carbon trading market will inevitably take into consideration the overall and long-term interests and coordinate the different requirements of different regions while meeting the demands for the whole country. The establishment of a future nationwide carbon trading market will be based on the experience and teaching of carbon verification work carried out in the pilot areas for carbon trading. Non-pilot areas may not simply copy the carbon verification work carried out in the pilot areas. Therefore,

the modeling role of pilot areas should be brought into full play, while the specific requirements for carbon verification in non-pilot areas should be considered. Supporting policies for carbon verification should be launched and improved to facilitate the progress of the nationwide carbon trading market, as well as to regulate and promote the carbon verification work across the country.

3. Regulating key GHG emission sources

Key GHG emission sources are the major GHG emitting entities and account for a large proportion of the total amount of GHG emissions. By regulating key sources of GHG emissions, verification methods can be enhanced, and the operability and accuracy of carbon verification improved. China's enterprise carbon emission accounting is still in the initial stage, and currently it is mainly the enterprises themselves are responsible for carbon emission detection and accounting. Hence, by identifying key GHG emission sources, enterprises may be guided to carry out emission accounting and emission reduction more effectively and efficiently, and key targets may be identified to improve the verification efficiency of third-party verification institutions.

4. Establishing and improving supervision of carbon verification

Based on the explorations of establishing a carbon verification and supervision system in the seven pilot areas, national carbon verification and supervision system should be established and improved. Monitoring and management of activities of carbon emission right trading verification institutions and personnel should be intensified. The responsibilities of government departments in terms of GHG emission reduction should be clearly specified. Formulation of GHG emission certification and accreditation standards and other work carried out by the China Certification and Accreditation Administration should be facilitated. Normal supervision of carbon verification should be facilitated. Local governments across the whole country may be guided to establish and improve carbon verification supervision systems, in order to create a situation in which local governments administer carbon verification and the China Certification and Accreditation Administration leads the supervision of carbon verification.

5. Intensifying international exchanges and cooperation

China should strictly follow the provisions of international treaties and conventions such as the UNFCCC and promote its national low-carbon development strategy in a pragmatic manner. In addition, China should actively conduct international exchanges and cooperation on carbon trading theories and practice, particularly the techniques of the MRV system. Further, China should actively introduce related international carbon verification standards to the domestic society and explain the carbon verification standards suitable for its own conditions to the international society, so that mutual recognition of carbon verification standards can be facilitated and effective channels provided for the docking of domestic and international carbon trading markets. In addition, third-party verification institutions should be encouraged and guided to explore international business.

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