2023 European Conference on Computing in Construction
40th International CIB W78 Conference
Heraklion, Crete, Greece
July 10-12, 2023

TOWARDS DEVELOPING A CARBON TRADING SYSTEM FOR THE CONSTRUCTION INDUSTRY: IDENTIFICATION OF MAJOR COMPONENTS

Augustine Senanu Komla Kukah[1], Xiaohua Jin[1], Robert Osei-Kyei[1] and Srinath Perera[1]
[1]School of Engineering Design & Built Environment, Western Sydney University,
Locked Bag 1797 Penrith NSW 2751, Australia

Abstract

Carbon trading is a system that aims to reduce the amount of greenhouse gases emitted by firms, especially those burning fossil fuels. Carbon trading systems were originally not designed for the construction industry and has little application in the construction sectors. The overall aim of this ongoing study is to develop a construction tailored carbon trading system. However, this paper presents on the initial stage which is to identify the major components for developing the carbon trading system. The four major components were market, strategies, plan, and policies. This study contributes to the construction industry's climate change mitigation.

Introduction

Emissions trading is an effective instrument in reducing greenhouse gas (GHG) emissions by serving as a market instrument (Cui et al. 2018). The principle underlying emissions trading is that entities must not exceed or go beyond the set carbon emission quotas that have been distributed by the government (Huang et al. 2022). Otherwise, these enterprises would have to purchase quotas from carbon emission markets or be made to face penalties (Gao et al. 2020). Carbon emissions trading has been implemented in varying sectors and countries worldwide (Bayer and Aklin 2020). Major sectors that existing carbon trading schemes have focused on include power, aviation, oil and gas, agriculture, maritime and manufacturing (Hood 2010; Nong et al. 2020; Yu et al. 2018).

Current carbon trading systems were originally not developed for the construction industry and carbon trading is a new concept to the construction industry (Kukah et al., 2022; Koriko 2021; Ng and Luk 2013; Oke et al. 2017). Current carbon trading systems have little application in the building and construction sectors (Du et al. 2023; Jiang et al. 2022; Li et al. 2022; Wang et al. 2017).

Past studies by Song et al. (2017); Shen et al. (2016); Ren et al. (2013) and Raines et al. (2005) explain that the construction and building sector has unique/special features and characteristics that affect the application of emissions trading system (ETS) in this industry. As compared to some other sectors that only emit carbon during their operation phase, the construction industry is unique as the input, processes and outputs involve both embodied and operating carbon.

Literature review

Carbon emission trading system came about in 1990s and has consistently been identified by various scholars as an efficient tool in addressing ineffective carbon emission quota allocation issues (Donehower 2008; Hua et al. 2011; Jiang et al. 2014; Wang et al. 2015; Zhang et al. 2020). Countries globally have adopted various market mechanism that internalize environmental externalities (Zhang et al. 2020). These include the Chinese trading system, European Union (EU) emissions trading system, the United Kingdom (UK) emissions trading system, the US California carbon market and New Zealand carbon emissions trading system etc. (Smith and Swierzbinski 2007; Zhang et al. 2020).

There currently exist two major types of emissions trading systems. These are: i. cap-and-trade and ii. baseline-and-credit schemes (Oke et al. 2017). These are further grouped into statutory and non-statutory. Statutory schemes are initiated and operated by the government and are compulsory. Non-statutory schemes do not involve government participation and members can join voluntarily (Vorster et al. 2011). Under cap-and-trade scheme, governments or international bodies like the European Union (EU) give out licenses to pollute (carbon permits) to firms (Radanne et al. 2010). A polluter can trade these permits with another firm (Graham-Rowe 2011). In simple terms, cap-and-trade scheme sets a limit on the amount of emissions that can be produced by an organization or firm while making provision to purchase extra allowances from organizations/firms that have not exhausted their full limits. This is the main approach behind EU ETS which is the world's largest carbon trading system. Baseline-and-credit on the other hand is based on emission intensity unlike cap-and-trade which is based on emissions (Oke et al. 2017). In baseline-and-credit scheme, a standard level of emissions is set and firms that reduce emissions below this base level will earn carbon credits which they can sell to other firms (Koriko 2021).

Another form of carbon emissions trading is off setting (Arendt et al. 2021; Calel et al. 2021; Shrestha et al. 2022; Thompson et al. 2022). Instead of emissions being cut at source, offsetting involves governments, finance institutions, individuals and companies financing emissions-saving projects outside the cap area (Kihulla 2014). The United Nation (UN) administered Clean Development Mechanism (CDM) is one of the largest offset schemes (Hultman et al. 2020; Lo and Cong 2022). According to United Nations Framework Convention on

Climate Change (UNFCCC), CDM has registered around 8064 projects so far as at the end of November 2022 with 9,594,110,246 certified emission reduction units (CERs) issued (Xu and Zhang 2022). CDM has also been noted to facilitate technology transfer to developing nations (Tang et al. 2022).

Components of carbon trading for the construction industry

According to international emission trading system (ETS) practices, some components of carbon trading consist of market trading, monitoring reporting and verification (MRV), legislation security, risk, cap determination, offset credit, allowance allocation and market linkage (Dong et al. 2016; Duan et al. 2014; Vlachou 2014; Zhang et al. 2017). Market trading is explained to consist of trading participants, transaction method, format for allowance, price of carbon credits and trading allowance category (Dong et al. 2016; Duan et al. 2014; Vlachou 2014; Zhang et al. 2017).

A study by Zhao et al. (2017) indicated the major components of carbon trading to constitute market, plan and policies. Another study by Xia et al. (2021) indicated strategies as another major component of carbon trading. This study therefore conceptualizes four major components for carbon trading in the construction industry. These components are explained in the subsequent sub-sections

Market

Considerable attention has been devoted by economists in defining relevant markets. Markets are explained essentially on two dimensions (Smale et al. 2006). These are the geographical market and product market. Market is explained at the combination of institutions, systems, procedures, infrastructure and social relations for parties to exchange goods or services. This exchange may be done through barter. However, exchange in a market is often done using money. Market is the process for establishing goods and services. In carbon trading, Zhao et al. (2016) and Fang et al. (2018) indicated a constituent of market to be capacity comprising of demand and supply. Zhang et al. (2019) explained another constituent of market to be structure where the market is classified to be either perfect competition, monopolistic competition, oligopoly, and monopoly. Shen et al. (2021) identified price setting as a constituent of market in carbon trading while Spash (2010) explained type of good as another constituent of market.

Carbon markets in carbon trading systems are a major tool in achieving the reduction of emissions by effectively putting price on pollution. These take different forms, from the mandatory trading of carbon permits to the voluntary projects that reduce emissions in order to earn carbon offsets. Carbon market enables individuals, firms and investors to trade in carbon offsets and carbon credits simultaneously (Kebe et al. 2011). This contributes to environmental crisis mitigation as well as the creation of new market opportunities.

From existing studies, carbon trading markets for the construction industry are closely influenced by population size, level of urbanization, economic development, industrial structure, resource endowment and technology level (Jiang et al. 2021; Li et al. 2021; Lin and Liu 2015; Safi et al. 2021). Figure 1 below illustrates market components and its sub-components.

[Please Insert Figure 1 here]

Strategy

Strategies explain how end goals are attained. Strategy often comprises setting priorities and goals. Relating to carbon trading, strategies detail the actions to execute in achieving set goals Zhao and Zhang (2018). Strategy can evolve as a pattern of activity which an organization adapts to (Donner et al. 2020). In a carbon trading system, the end goal is to contribute to the reduction in greenhouse gas emissions (Xia et al. 2021). In the construction industry, when the carbon trading system is running and operational, it is expedient to measure its efficiency to see if it is achieving its goals (Wang et al. 2022).

Trading methodologies refer to the principles that are used to successfully trade in a trading system (Kaufman 2013). These principles for operation revolve on the desire for long term profitability as well as provision of value for increased trading. Regarding carbon trading, the major methodologies underpinning the trading scheme are the cap-and-trade, joint implementation (JI) and clean development mechanism (CDM).

A major trading strategy in carbon trading for the construction industry is the decision on the allocation of emission permits. A major option considered is auction by the government when the scheme has equivalence to carbon tax that has been set at the level of auction price taking in cognizance the auction rules. Another option is through free allocation using formulae related to current emissions. These two options provide incentive for reducing emissions. Auctions transfer resources from the emitters to government causing government to make revenue. Free allocation seems to provide assets through tradable property rights to polluting firms. For any trading scheme, proportion of the emission permits can be allocated through auctioning while the remaining can be allocated for free. This provides flexibility.

Emissions quota allocation has a role to play in the determination of reduction responsibility (Zhou and Wang 2016). There are mainly two methods for distributing quota allowance (Chi et al. 2022). These are the grandfathering method and the benchmark-based method in distributing quotas. The most commonly used method is grandfathering, and it has the simplest requirements for data according to Zhou and Wang (2016). Figure 2 below illustrates the strategies component and sub-components.

[Please Insert Figure 2 here]

Plan

Plan involves a list of consistently arranged steps that are set before undertaking a trading deal (Smith 2020). Plan serves as an objective guidance in trading and serves as a reminder of overall long-term and short-term goals (Adair 2010). Trading plan differs from trading strategy, which is rather a determinant of trade entry and exits (Baron et al. 2019). Plan in carbon trading encompasses an orderly arrangement of parts of an overall goal, design or objective in developing carbon trading schemes/systems (Montagnoli and De Vries 2010). After the strategies have been formulated in a carbon trading system, a plan is next required. Zhao et al. (2017) posited that financial resources are required in running a carbon trading system. Hepburn (2007) explained the need for revenue management in carbon trading under plan while another research by Montagnoli and De Vries (2010) indicated the role of risk management as a constituent of plan in carbon trading systems.

Revenue management is an essential part of plan in carbon trading for the construction industry (Narassimhan et al. 2018). In the construction industry, when compared to large investment decisions like purchase of land, developing construction works and installation of equipment, the issues of energy efficiency and its improvement is not given much priority (Jiang, 2009). Relative costs of energy are also low when compared to operation costs in building projects. Plans must therefore be made in tracking revenues that are generated through carbon trading. Tracking the generation and use of revenue in an emissions trading system is useful for corroborating the extent to which the trading system seeks to balance the environmental, social, political and economic needs arising out of the implantation of carbon trading (Narassimhan et al. 2017). According to Klenert et al. (2018), in 2015 alone, carbon pricing accounted for US$26 billion in revenues globally. For the construction industry, revenues from carbon trading and actioned allowances can be utilized in climate change reduction; minimizing ETS administrative costs; lessening burden of compliance costs for firms; augmenting public goods expenditure thereby addressing distributional inequities; minimizing budget deficits; lowering distortionary taxes and increasing flow of climate finance from developed countries to developing countries (Bowen 2015; Narassimhan et al. 2018). Figure 3 below illustrates the plan components and sub-components.

[Please Insert Figure 3 here]

Policies

Policies comprises of deliberate systems of guidelines that help achieve satisfactory outcomes and guide decision making. Policies are mainly adopted by governance bodies within organizations (Talberg and Swoboda 2013). In carbon trading, policy comprise statements of intent and are implementable protocols or procedures specific to the trading. Relating to carbon trading system, Zhao et al. (2017) opined that policy is a major component in the development of carbon trading. For the Chinese construction industry, in 2011, policy called "Twelfth Five Year Plan" were emanated to reduce energy consumption and carbon emissions density per unit of Gross Domestic Product (GDP) by 16 to 17% by the year 2015 compared to 2010 emission levels (Chen et al., 2015). Studies by Zhao and Zhang (2018) and Bobadilla et al. (2018) found supervision to be a constituent of policy. Perdan and Azapagic (2011) researched into banking mechanisms as constituent of plan. Zhao et al. (2017) and Talberg and Swoboda (2013) explained legislations as being part of policy in trading systems. Hart and Zhong (2014), Werber (2011) and Hasselknippe (2003) in their studies found compliance to be constituent of policy in a trading system.

Economic conditions have an influence on the stringency of caps set for carbon trading. For example, in the Chinese pilot trading schemes, Guangdong increased their emission cap. This was to allow for an increase in industrial production. The city of Hubei on the other hand decreased their cap as a reflection of new economic growth patterns. City of Chongqing reduced their cap by 4.13 percent a year. On the other hand, Shanghai, Beijing, Shenzhen and Tianjin left their caps unchanged during 2013 to 2015 (Xiong et al. 2017). Figure 4 below illustrates the policies component and sub-components.

[Please Insert Figure 4 here]

Conclusions

Emissions trading has been identified to be a reasonable panacea in curbing future levels of greenhouse gas emissions. This study identified and presented the components of carbon trading for the construction industry. These components were market, strategies, plan and policies. In the next stage of this ongoing research, system dynamics (SD) technique will be used to model the relationship among the various components. The interactions in these models will comprise model verification, model development, model testing and model simulations. These will be reported in subsequent papers.

Acknowledgments

This study is funded by the Doctoral Research scholarship kindly provided by Western Sydney University, Australia.

Figure 1: Market component and sub-components

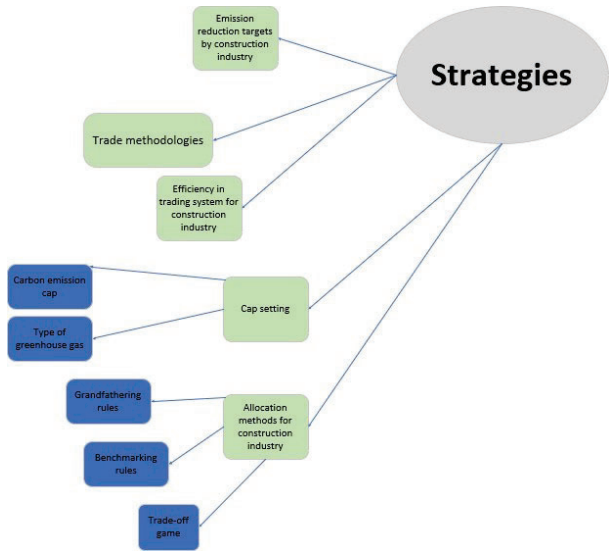

Figure 2: Strategy components and sub-component

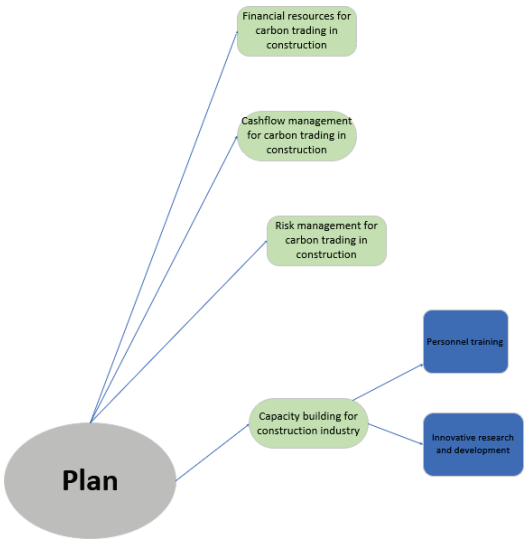

Figure 3: Plan components and sub-components

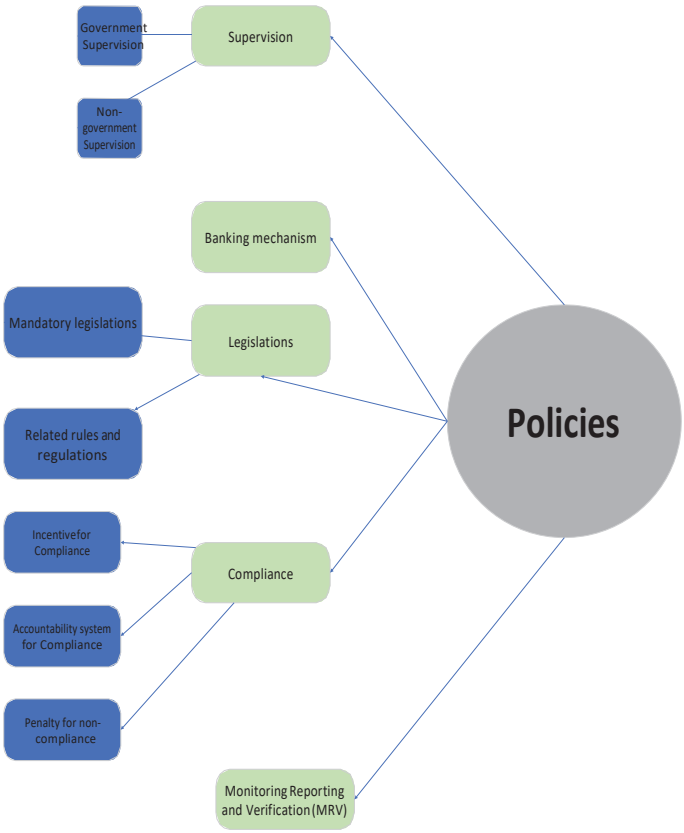

Figure 4: Policies component and sub-components

References

Adair, J. (2010). Strategic leadership: How to think and plan strategically and provide direction, Kogan Page Publishers.

Arendt, R., Bach, V. and Finkbeiner, M. (2021). 'Carbon offsets: an LCA perspective', in Progress in Life Cycle Assessment 2019, Springer, pp. 189-212.

Baron, M., Brogaard, J., Hagströmer, B. and Kirilenko, A. (2019). 'Risk and return in high-frequency trading', Journal of Financial and Quantitative Analysis, vol. 54, no. 3, pp. 993-1024.

Bayer, P. and Aklin, M. (2020). 'The European Union emissions trading system reduced CO2 emissions despite low prices', Proceedings of the national academy of sciences, vol. 117, no. 16, pp. 8804-8812.

Bobadilla, U.J., Ganti, G. and Montoya, F.A.C. (2018). 'China's Emissions Trading System'.

Bowen, A. (2015). 'Carbon pricing: how best to use the revenue', Policy Brief, Grantham Research Institute on Climate Change and the Environment.

Calel, R., Colmer, J., Dechezleprêtre, A. and Glachant, M. (2021). 'Do carbon offsets offset carbon?'.

Chen, Y., Jiang, P., Dong, W., and Huang, B. (2015). Analysis on the carbon trading approach in promoting sustainable buildings in China. Renewable Energy, 84, 130-137.

Chi, Y-y., Zhao, H., Hu, Y., Yuan, Y-k. and Pang, Y-x. (2022). 'The impact of allocation methods on carbon emission trading under electricity marketization reform in China: A system dynamics analysis', Energy, vol. 259, p. 125034.

Cui, J. Zhang, J. and Zheng, Y. (2018). 'Carbon pricing induces innovation: evidence from China's regional carbon market pilots', vol. 108, pp. 453-457.

Donehower, J. (2008). 'Analyzing carbon emissions trading: a potential cost-efficient mechanism to reduce carbon emissions', Envtl. L., vol. 38, p. 177.

Donner, M., Gohier, R. and de Vries, H. (2020). 'A new circular business model typology for creating value from agro-waste', Science of The Total Environment, vol. 716, p. 137065.

Du, Q., Wang, Y., Pang, Q., Hao, T. and Zhou, Y. (2023). 'The dynamic analysis on low-carbon building adoption under emission trading scheme', Energy, vol. 263, p. 125946.

Fang, G., Tian, L., Liu, M., Fu, M. and Sun, M. (2018). 'How to optimize the development of carbon trading in China—Enlightenment from evolution rules of the EU carbon price', Applied Energy, vol. 211, pp. 1039-1049. Gao, Y., Li, M., Xue, J. & Liu, Y. (2020). 'Evaluation of effectiveness of China's carbon emissions trading scheme in carbon mitigation', Energy Economics, vol. 90, p. 104872.

Graham-Rowe, D. (2011). 'Agriculture: beyond food versus fuel', Nature, vol. 474, no. 7352, pp. S6-S8.

Hasselknippe, H. (2003). 'Systems for carbon trading: an overview', Climate Policy, vol. 3, no. sup2, pp. S43- S57.

Hepburn, C. (2007). 'Carbon trading: a review of the Kyoto mechanisms', Annual review of environment and resources, vol. 32, no. 1, pp. 375-393.

Hood, C. (2010). 'Reviewing existing and proposed emissions trading systems'.

Hua, G., Cheng, T. and Wang, S. (2011). 'Managing carbon footprints in inventory management', International Journal of Production Economics, vol. 132, no. 2, pp. 178-185.

Huang, W., Wang, Q., Li, H., Fan, H., Qian, Y. and Klemeš, J.J. (2022). 'Review of recent progress of emission trading policy in China', Journal of cleaner Production, vol. 349, p. 131480.

Hultman, N., Lou, J. and Hutton, S. (2020). 'A review of community co-benefits of the clean development mechanism (CDM)', Environmental Research Letters, vol. 15, no. 5, p. 053002.

Jiang, P. (2009). A low carbon sustainable strategy using CDM methodological approach to large commercial buildings in Beijing and Shanghai (Doctoral dissertation, University of East Anglia).

Jiang, J.J., Ye, B. and Ma, X.M. (2014). 'The construction of Shenzhen′ s carbon emission trading scheme', Energy Policy, vol. 75, pp. 17-21.

Jiang, M., An, H., Gao, X., Jia, N., Liu, S. and Zheng, H. (2021). 'Structural decomposition analysis of global carbon emissions: the contributions of domestic and international input changes', Journal of environmental management, vol. 294, p. 112942.

Jiang, T., Song, J. and Yu, Y. (2022). 'The influencing factors of carbon trading companies applying blockchain technology: evidence from eight carbon trading pilots in China', Environmental Science and Pollution Research, vol. 29, no. 19, pp. 28624-28636.

Kaufman, P.J. (2013). Trading Systems and Methods,+ Website, vol. 591, John Wiley & Sons.

Kebe, A., Bellassen, V. and Leseur, A. (2011). Voluntary carbon offsetting by local authorities: practices and lessons, auto-saisine.

Kihulla, E.M. (2014). 'An exploratory assessment of the opportunities and challenges of carbon trading in Tanzania'.

Klenert, D., Mattauch, L., Combet, E., Edenhofer, O., Hepburn, C., Rafaty, R. (2018). 'Making carbon pricing work for citizens', Nature Climate Change, vol. 8, no. 8, pp. 669-677.

Koriko, O. (2021). Appraisal of carbon trading practices in the construction industry in Lagos State, Nigeria, Federal University of Technology, Akure.

Kukah, A.S.K., Jin, X., Osei-Kyei, R. and Perera, S. (2022). A conceptual framework for carbon trading in the construction industry. 45th AUBEA Conference 2022: Global Challenges in a Disrupted World: Smart, Sustainable and Resilient Approaches in the Built Environment. *Editors:* Perera, S. and Hardie, M.

Li, L., Duan, M., Guo, X. and Wang, Y. (2022). 'The Stimulation and Coordination Mechanisms of the Carbon Emission Trading Market of Public Buildings in China. Front', Sustainable Energy Systems With Policies in China, vol. 9, p. 715504.

Li, R., Wang, Q., Liu, Y. and Jiang, R. (2021). 'Per-capita carbon emissions in 147 countries: the effect of economic, energy, social, and trade structural changes', Sustainable Production and Consumption, vol. 27, pp. 1149-1164.

Lin, B. and Liu, H. (2015). 'China's building energy efficiency and urbanization', Energy and buildings, vol. 86, pp. 356-365.

Lo, A.Y. and Cong, R. (2022). 'Emission reduction targets and outcomes of the Clean Development Mechanism (2005–2020)', PLOS Climate, vol. 1, no. 8, p. e0000046.

Montagnoli, A. and De Vries, F.P. (2010). 'Carbon trading thickness and market efficiency', Energy Economics, vol. 32, no. 6, pp. 1331-1336.

Narassimhan, E, Gallagher, KS, Koester, S & Alejo, JR 2017, 'Carbon pricing in practice: a review of the evidence', Climate Policy Lab: Medford, MA, USA.

Narassimhan, E, Gallagher, KS, Koester, S & Alejo, JR 2018, 'Carbon pricing in practice: A review of existing emissions trading systems', Climate Policy, vol. 18, no. 8, pp. 967-991.

Ng, ST & Luk, WS 2013, 'Applicability of existing carbon trading schemes to the construction industry', Czech Technical University in Prague, pp. 753-756.

Nong, D, Nguyen, TH, Wang, C & Van Khuc, Q 2020, 'The environmental and economic impact of the emissions trading scheme (ETS) in Vietnam', Energy Policy, vol. 140, p. 111362.

Oke, AE, Aigbavboa, CO & Dlamini, SA 2017, 'Carbon emission trading in South African construction industry', Energy Procedia, vol. 142, pp. 2371-2376.

Perdan, S & Azapagic, A 2011, 'Carbon trading: Current schemes and future developments', Energy Policy, vol. 39, no. 10, pp. 6040-6054.

Radanne, P, Diaz, E & Xie, K 2010, 'Analysis brief on the climate negotiations', Cancún–COP.

Raines, FD, Sahadi, RJ, Berlin, K, Desiderio, M, Lesmes, S, Cavey, EA et al. 2005, 'System and method for residential emissions trading', Google Patents.

Ren, H, Lu, Y, Cai, W & Xie, Q 2013, 'Study on framework of buildings' carbon emissions trading in China', Urban Dev Stud, vol. 20, pp. 70-76.

Safi, A, Chen, Y, Wahab, S, Ali, S, Yi, X & Imran, M 2021, 'Financial instability and consumption-based carbon emission in E-7 countries: the role of trade and economic growth', Sustainable Production and Consumption, vol. 27, pp. 383-391.

Shen, L, Song, X, Wu, Y, Liao, S & Zhang, X 2016, 'Interpretive Structural Modeling based factor analysis on the implementation of Emission Trading System in the Chinese building sector', Journal of cleaner Production, vol. 127, pp. 214-227.

Shen, L, Wang, X, Liu, Q, Wang, Y, Lv, L & Tang, R 2021, 'Carbon trading mechanism, low-carbon e-commerce supply chain and sustainable development', Mathematics, vol. 9, no. 15, p. 1717.

Shrestha, A, Eshpeter, S, Li, N, Li, J, Nile, JO & Wang, G 2022, 'Inclusion of forestry offsets in emission trading schemes: insights from global experts', Journal of Forestry Research, vol. 33, no. 1, pp. 279-287.

Smale, R, Hartley, M, Hepburn, C, Ward, J & Grubb, M 2006, 'The impact of CO2 emissions trading on firm profits and market prices', Climate Policy, vol. 6, no. 1, pp. 31-48.

Smith, RD 2020, Strategic planning for public relations, Routledge.

Smith, S & Swierzbinski, J 2007, 'Assessing the performance of the UK Emissions Trading Scheme', Environmental and Resource Economics, vol. 37, no. 1, pp. 131-158.

Song, X, Shen, L, Yam, MC & Zhao, Z 2017, 'SNA based identification of key factors affecting the implementation of emission trading system (ETS) in building sector: a study in the context of China', Springer, pp. 595-606.

Spash, C.L. (2010). 'The brave new world of carbon trading', New Political Economy, vol. 15, no. 2, pp. 169-195.

Talberg, A. and Swoboda, K. (2013). 'Emissions trading schemes around the world'.

Tang, W., Du, S., Hu, L., Wang, B. and Zhu, Y. (2022). 'The effects of leadership in Clean Development Mechanism low-carbon operations', Transportation Research Part E: Logistics and Transportation Review, vol. 158, p. 102575.

Thompson, N.M., Hughes, M.N., Nuworsu, E.K., Reeling, C.J., Armstrong, S. and Mintert, J. (2022). 'Opportunities and challenges associated with “carbon farming” for US row-crop producers', Choices, vol. 37, no. 316-2022-1149.

Vorster, S., Winkler, H. and Jooste, M. (2011). 'Mitigating climate change through carbon pricing: An emerging policy debate in South Africa', Climate and Development, vol. 3, no. 3, pp. 242-258.

Wang, P., Dai, H-c., Ren, S-y., Zhao, D-q. and Masui, T. (2015). 'Achieving Copenhagen target through carbon emission trading: Economic impacts assessment in Guangdong Province of China', Energy, vol. 79, pp. 212-227.

Wang, X., Huang, J. and Liu, H. (2022), 'Can China's carbon trading policy help achieve Carbon Neutrality?—A study of policy effects from the Five-sphere Integrated Plan perspective', Journal of environmental management, vol. 305, p. 114357.

Wang, Z., Zhao, J. and Li, M. (2017). 'Analysis and optimization of carbon trading mechanism for renewable energy application in buildings', Renewable and Sustainable Energy Reviews, vol. 73, pp. 435-451. Werber, J.M. (2011). Models for Accountability to Combat Non-Compliance in Carbon Trading, The George Washington University.

Xia, Q., Li, L., Dong, J. and Zhang, B. (2021). 'Reduction Effect and Mechanism Analysis of Carbon Trading Policy on Carbon Emissions from Land Use', Sustainability, vol. 13, no. 17, p. 9558.

Xiong, L., Shen, B., Qi, S., Price, L. and Ye, B. (2017). 'The allowance mechanism of China’s carbon trading pilots: A comparative analysis with schemes in EU and California', Applied Energy, vol. 185, pp. 1849-1859.

Xu, J. and Zhang, Y. (2022). 'Has the international climate regime promoted climate justice? Evidence from Clean Development Mechanism projects in China', Climate Policy, vol. 22, no. 2, pp. 222-235.

Yu, Z., Geng, Y., Dai, H., Wu, R., Liu, Z. and Tian, X. (2018). 'A general equilibrium analysis on the impacts of regional and sectoral emission allowance allocation at carbon trading market', Journal of cleaner Production, vol. 192, pp. 421-432.

Zhang, H., Zhang, R., Li, G., Li, W. and Choi, Y. (2019). 'Sustainable feasibility of carbon trading policy on heterogenetic economic and industrial development', Sustainability, vol. 11, no. 23, p. 6869.

Zhang, Y., Li, S., Luo, T. and Gao, J. (2020). 'The effect of emission trading policy on carbon emission reduction: evidence from an integrated study of pilot regions in China', Journal of cleaner Production, vol. 265, p. 121843.

Zhao, X-g., Jiang, G-w., Nie, D. and Chen, H. (2016). 'How to improve the market efficiency of carbon trading: A perspective of China', Renewable and Sustainable Energy Reviews, vol. 59, pp. 1229-1245.

Zhao, X-g., Wu, L. and Li, A. (2017). 'Research on the efficiency of carbon trading market in China', Renewable and Sustainable Energy Reviews, vol. 79, pp. 1-8.

Zhao, X-g. and Zhang, Y-z. (2018). 'The system dynamics (SD) analysis of the government and power producers’ evolutionary game strategies based on carbon trading (CT) mechanism: A case of China', Sustainability, vol. 10, no. 4, p. 1150.

Zhou, P. and Wang, M. (2016). 'Carbon dioxide emissions allocation: A review', Ecological economics, vol. 125, pp. 47-59.