Wijayawardena, D.S.I. and Ranadewa, K.A.T.O., 2025. Carbon financing in construction: Review of benefits and barriers. In: Waidyasekara, K.G.A.S., Jayasena, H.S., Wimalaratne, P.L.I. and Tennakoon, G.A. (eds). *Proceedings of the 13th World Construction Symposium*, 15-16 August 2025, Sri Lanka. pp. 372-384. DOI: https://doi.org/10.31705/WCS.2025.28. Available from: https://ciobwcs.com/papers/

CARBON FINANCING IN CONSTRUCTION: REVIEW OF BENEFITS AND BARRIERS

D.S.I. Wijayawardena[1] and K.A.T.O. Ranadewa[2]

ABSTRACT

The buildings and construction sector is responsible for 37% of global GHG emissions. Given the inefficacy of traditional methods in reducing GHG emissions, the adoption of sustainable strategies including low-carbon materials, energy-efficient practices, and the integration of renewable energy has become essential. Among these, Carbon Financing (CF) stands out as a mechanism that not only reduces emissions but also provides economic opportunities, making it highly attractive to investors. CF enables stakeholders to earn and trade carbon credits by reducing emissions allowing construction firms to monetise their environmental efforts. Hence this study aims to systematically review the benefits and barriers of CF for sustainable construction. The study conducted a systematic literature review on Carbon Financing (CF) in construction utilising the PRISMA framework. From an initial 126 articles, 91 articles were shortlisted for detailed analysis. Findings reveal a range of CF instruments categorised as primary products and derivatives, to manage carbon emissions and enhance market liquidity. Additionally, the study highlighted both the economic and environmental benefits of CF, including promoting green job creation, attracting investments in sustainable energy, and supporting biodiversity conservation. However, factors including lack of understanding, limited policy support, and a need for innovative CF products have been discovered as challenges faced in CF adoption. The study concluded that CF holds significant potential for transforming the construction sector into a more sustainable industry. This research contributes to the existing body of knowledge by providing a blueprint for integrating CF into construction practices while setting the stage for further research and practical application towards global sustainability goals.

Keywords: *Carbon Finance (CF); Carbon Market; Carbon Trading; Construction Industry.*

1. INTRODUCTION

Being the most resource-consuming industry (Feng et al., 2022), the construction industry is responsible for more than 40% of raw material consumption (Dixit et al., 2022) and over 30% of the world's energy consumption (Banawi & Bilec, 2014). This has led to the emission of significant amounts of harmful greenhouse gases (GHGs) into the environment. GHGs absorb and re-emit thermal radiation, thereby contributing to the warming of the planet's atmosphere. The principal GHGs include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (Brander & Davis, 2012;

[1] Research Assistant, Department of Building Economics, University of Moratuwa, Sri Lanka, wijayawardenadsi.24@uom.lk

[2] Senior Lecturer, Department of Building Economics, University of Moratuwa, Sri Lanka, tharushar@uom.lk

Shirinbakhsh & Harvey, 2021). GHG emissions significantly contribute to climate change, threatening ecosystems, human health, and economic stability (Ling, 2021). To mitigate carbon emissions from the construction industry, various sustainable strategies can be employed. The adoption of low-carbon materials and energy-efficient practices (Zhang et al., 2024), integration of life cycle assessment (LCA), green supply chain management (GSCM), and the utilisation of renewable materials have emerged as viable approaches to address these issues. Among all these viable approaches carbon financing stands at the forefront of the global battle against carbon emissions. (Chien, 2024). CF, a branch of environmental finance, focuses on creating financial tools to achieve environmental goals and manage environmental risks (Li & Liu, 2011), and solve climate issues (Liu et al., 2015). It involves investment and financing activities within the low-carbon economy, aligned with the Kyoto Protocol of 1997 (Li & Liu, 2011) and the Paris Agreement of 2015 (Delbeke et al., 2019). One notable real-world example of carbon finance in practice is the Clean Development Mechanism (CDM) projects. CDM projects are sustaible initaitives focused on emission reduction (Mok et al., 2014). Later, the volume of emissions reduced is quantified and converted into Certified Emission Reductions (CERs), which can be traded on carbon markets to generate financial returns, becoming the (carbon) financing of the project. CF can influence carbon trading, enhance research and development efforts (Zhu et al., 2019), and encourage innovation of new materials with lower embodied carbon (Bamgbade et al., 2019).

CF can encourage industries to create green jobs (Wang et al., 2024) and it stimulates local economies to perform well (Chen & Wu, 2023). Additionally, due to CF's ability to influence low-carbon construction, it can reduce long-term operational costs of building making it a financially attractive sustainable practice (Topak et al., 2019). Carbon financial instruments can be effective in the construction industry, particularly when the upfront costs of adopting sustainable practices are significant (Liu et al., 2019). Despite its benefits, the adoption of CF face numerous challenges in construction industry (Wu et al., 2022). Lack of understanding on CF, insufficient knowledge about CF systems and shortage of experts in CF has made it less popular among the public (Liu et al., 2015). Additionally, existing policies, regulations, and legal frameworks not being robust enough to support CF, and lack of innovation in CF products (Parenteau & Cao, 2016) are two noteworthy challenges. The absence of a nationally unified carbon trading platform also poses problems in many countries (Wu et al., 2022). These obstacles highlight the complexity of implementing and adopting CF effectively in the construction industry.

Despite carbon financing's ability to empower sustainable construction, the integration of these financial mechanisms into the construction sector remains fragmented and underexplored. The existing literature offers a limited comprehensive analysis on the effectiveness of carbon financing in promoting sustainable construction practices. Recent literature, including Murali et al. (2024), investigates key enablers for integrating deconstruction and CF to enhance sustainable and resilient construction in the Industry 5.0 era. This complements Zhou and Li (2019), who explored the challenges and progress in implementing CF in construction, providing a foundation for understanding the obstacles faced. Oke et al. (2024) further contribute by identifying barriers to CF adoption and proposing practical solutions. Jiang et al. (2020) analyse the interplay between carbon trading, financing costs, and emission reduction strategies within the construction supply chain, shedding light on the financial mechanisms that influence emission reductions.

Even though there are studies on enablers, challenges, barriers, and solutions regarding the financial dynamics of carbon trading, there is a lack of an integrated framework that synthesises these various aspects. Each study, though valuable, tends to focus on specific dimensions without holistically addressing how these elements interact. For instance, studies such as Li (2020), Jiang et al. (2017), and Zhou and Li (2019) focuses on the Chinese construction industry, while research by Woo et al. (2020) and Eicker et al. (2020) primarily examine the US market. This regional focus creates a fragmented understanding, leaving a significant gap in understanding how carbon financing can be systematically applied to drive sustainability across the global construction industry. Therefore, this research aims to investigate the integration of CF into sustainable construction practices, with a specific focus on identifying the key benefits and barriers to its implementation within the construction industry. The systematic review will offer insights into the current state of knowledge, identify best practices, and propose recommendations for integrating carbon financing more effectively into the construction industry's sustainability strategies.

This paper is structured to provide a comprehensive exploration of the research topic. It begins with an introduction that outlines the background, significance, and aim of the study. The methodology section details the systematic approach employed to collect and analyse CF data. This is followed by a thorough systematic literature review, the paper reveals the CF instruments, key challenges, and benefits associated with the application of CF in the construction industry. Finally, the paper concludes with a summary of key findings, along with practical recommendations for future research and industry application.

2. RESEARCH METHODOLOGY

A literature review is a widely used technique in construction-related research to expand the body of knowledge on specific topics (Chen et al., 2022). To identify and select a relevant topic in academia, a systematic review of previous research is essential (Ayat et al.,2021). In this study, a scholarly journal article on CF in the construction sector was located using the Scopus search engine. Scopus was chosen for three main reasons: (1) it has been extensively used in construction review research (Osei-Kyei & Chan, 2015); (2) it is an effective tool for conducting literature reviews (Ghaleb et al., 2022); and (3) it is more accurate and reliable compared to other search engines like PubMed, Google Scholar, and Web of Science (Ahmad et al., 2021). The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework was selected as the optimal methodology for this study after considering various systematic literature review methods. According to Shahruddin and Zairul (2020), PRISMA enhances the quality of evidence-based results and ensures transparency in the literature selection process. Moher et al. (2015) highlight that PRISMA's analytical and methodological approach is clear and straightforward. Further, Karunarathna et al. (2024) emphasise that a well-defined research topic is for a successful systematic review. The PRISMA framework explicitly incorporates the PICO (Populations, Interventions, Comparator, and Outcome) method for developing research questions of the study, as it facilitates literature reviews that address specific queries (Hosseini et al., 2024). Following Figure 1 presents the PRISMA flow diagram used for the study.

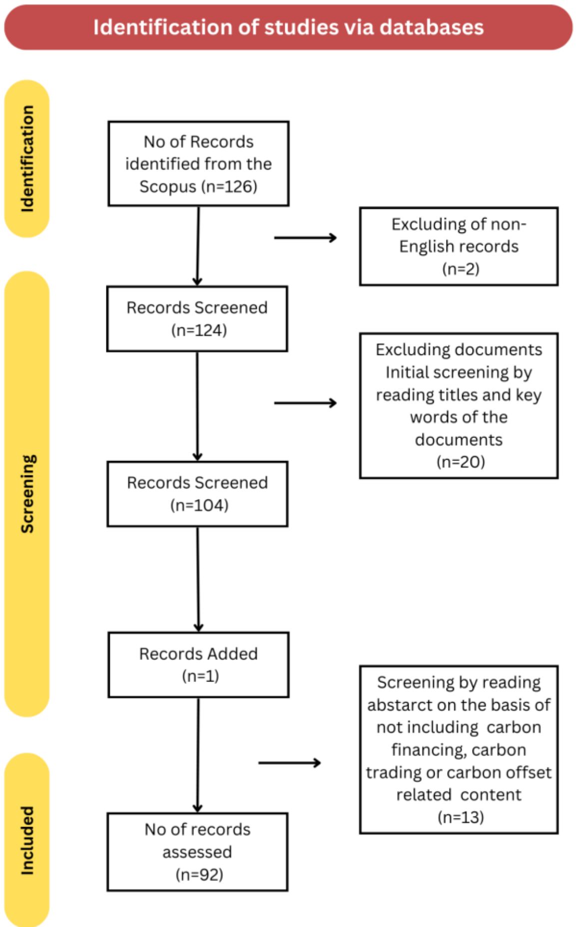

Figure 1: PRISMA flow diagram used for the study

The main search string used to retrieve bibliometric data related to the research area of concern was: ("carbon finance" OR "carbon financing" OR "carbon credit" OR "carbon trading" OR "carbon trade" OR "carbon offsetting" OR "carbon offset" OR "carbon accounting") AND ("construction industry" OR "building sector" OR "construction projects" OR "construction management"). Furthermore, more keywords and exclusion criteria have been used in the Scopus database to select relevant literature. Next, the screening process was performed by including journals, conference papers, and unpublished theses. Accordingly, 126 articles were selected from the search protocol. Due to language barriers, 2 non-English articles were excluded. Due to time and resource limitations, the search criteria were restricted to 'Article title, Abstract, Keywords.' From the remaining 124 papers, inclusion and exclusion criteria were applied to identify the most relevant papers and conduct a qualitative content analysis. The product-related papers, non-construction related papers, and papers that did not focus mainly on CF were excluded. As illustrated in Figure 1, 91 papers out of 124 were shortlisted. Papers have been reviewed using both content analysis and descriptive analysis. The content analysis was used to review the paper's contents thoroughly in broader themes such as (1) benefits of CF; (2) CF instruments; (3) challenges in CF; and (4) strategies to overcome the challenges. The research findings are presented in the two sections of the 'Findings and Discussion' section.

3. FINDINGS AND DISCUSSIONS

As GHG emissions continue to rise at alarming rates, the need for sustainable measures, including CF, is more critical than ever. Liu et al. (2019) explained that CF explores the financial implications of living in an environment where emissions of carbon dioxide and other GHGs carry a cost. Borghesi et al. (2015) describe carbon finance as encompassing activities that promote carbon emission reductions, such as investing in certified emission reductions (CERs) and carbon emissions trading. Liu et al. (2015) assert that carbon finance serves as an economic measure aimed at effectively addressing the climate problem. As noted by Su et al. (2023), CF includes cash flows from the sale of carbon credits, which represent the right to emit a certain amount of carbon dioxide. The UNHCR notes that CF is an innovative funding tool that places a financial value on carbon emissions, allowing companies to offset their emissions by purchasing credits from sustainable projects. Hence, CF is mostly integrated with trading carbon credits (Li & Liu, 2011; Zhou & Li, 2019).

Building upon this foundation, the ability to trade carbon credits and earn profits has become one of the main reasons for the popularity of CF as a business opportunity and investment among investors and businessmen (Su et al., 2023). The CF business primarily consists of two types. The first is the credit business, which focuses on the transformation of traditional industries through low-carbon upgrades, including CDM project investment and financing. The second is the intermediary business, which involves designing and developing carbon financial derivatives (Zhang & An, 2014). According to Labatt and White (2011), CF involves financial instruments and approaches that address climate issues through market-based solutions in a carbon-constrained world. Hence, these has become indispensable trading products in the CF market (Zhu et al., 2022). CF derivatives also known as CF instruments mainly include carbon futures, carbon options, and carbon swaps (Zhang & An, 2014; Sandor & Diperna, 2023; Liu & Li, 2024). Trading of CF derivatives occurs either on exchanges or over-the-counter (OTC) (Spilker & Nugent, 2022; Xu & Liu, 2023). These derivatives serve purposes such as hedging, carbon credit trading, and value discovery.

In light of these developments in the CF context, placing a monetary value on carbon emissions offers significant incentives and encouragement for construction firms to lower their emissions. Hence, CF has become an emerging area of focus within the construction industry. To further explore the role of CF in the construction industry, both content analysis and descriptive analysis were conducted to examine relevant literature and publication trends.

3.1 DESCRIPTIVE ANALYSIS

The publication trend of empirical studies conducted through the past years and the geographical distribution of related studies are insights through descriptive analysis.

3.1.1 Geographical Analysis

Understanding the geographical origins of research on CF within the construction industry offers valuable insights into global scholarly engagement and regional focus areas. As illustrated in Figure 2, the geographical distribution of CF-related publications demonstrates a growing global academic interest in applying CF principles to the built environment, underlining its rising relevance in achieving sector-wide sustainability goals.

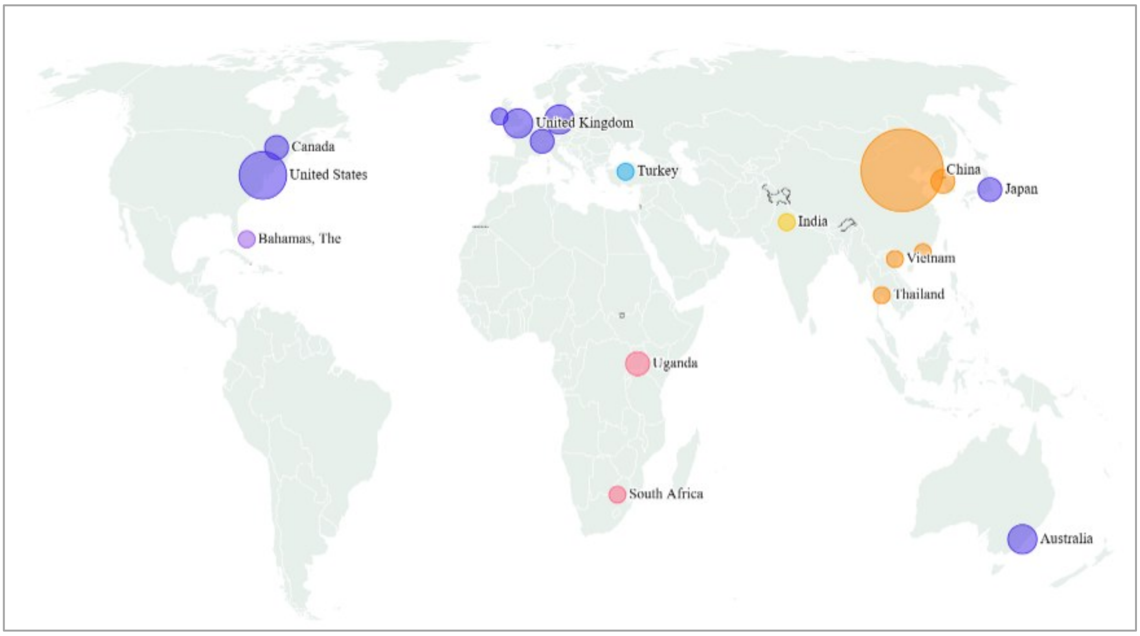

Figure 2: Geographical distribution of publications for CF of construction industry

The geographical distribution of publications illustrated in Figure 2 reveals significant disparities in research output on Carbon Financing (CF) within the construction industry across different regions. Countries like China and the United States emerge as leading contributors, reflecting their advanced commitments to climate action, regulatory frameworks supporting carbon markets, and institutional capacity to conduct large-scale research. China, in particular, dominates with 24 publications, likely driven by its national emissions trading scheme and increasing focus on green finance. In contrast, regions such as the EU and Europe, despite their progressive climate policies, show surprisingly lower publication counts, possibly due to data aggregation under broader European initiatives or journal indexing practices. Developed countries like Australia, Germany, the UK, and Canada exhibit moderate contributions, indicating a steady interest in integrating CF into sustainable construction practices. Meanwhile, developing nations including Uganda, India, South Africa, Vietnam, and Thailand demonstrate minimal scholarly activity. This limited engagement can be attributed to constraints such as resource scarcity, limited research infrastructure, and the prioritisation of socio-economic development over academic inquiry.

3.2 CONTENT ANALYSIS

The benefits and challenges associated with the implementation of carbon financing are thoroughly examined through the content analysis.

3.2.1 Benefits of CF

CF offers numerous benefits that significantly contribute to sustainable development and environmental protection. Table 1 presents the benefits of utilising CF.

Table 1: Benefits of utilising CF

Benefits	Sources
Global (Carbon) Emission Reductions	[1], [2], [3], [4], [5], [6],
Creation of Green Jobs	[4], [5]
Sustainable Energy Initiatives	[1], [2], [3], [4], [5], [6]
Biodiversity Protection	[7]
Climate Resilience	[1], [6]
Influence water quality trading	[8]
Cleaner Air and Health Benefits	[3]
Combatting Greenwashing	[9], [10]
Attract New Investments	[1]
Diversified Income for Communities	[1]
Economic Development for countries	[1]
Environmental Protection	[1], [5], [6]
Banks can enhance their capacity	[1]
International Cooperation	[1]

(1-Zhou & Li, 2019); (2- Yang & Luo, 2020); (3- Cai et al.,2016); (4- Wang et al., 2024); (5- Yu et al., 2021); (6- Firdaus & Arkananta, 2024); (7- Essl et al., 2018)

CF offers numerous benefits that significantly contribute to sustainable development and environmental protection. Among its primary advantages is the reduction of global carbon emissions, a critical step in combating climate change (Zhou & Li, 2019; Wang, 2021). The Olkaria II Unit 3 Geothermal Expansion Project in Kenya, the country's first CDM project to issue CERs, can be highlighted as a strong example of effective carbon financing (World Bank, n.d.). The project adds 276 gigawatts to the national grid while reducing 149,632 tonnes of carbon dioxide per year, making it a profitable project for both humans and the environment. In terms of climate resilience, CF plays a pivotal role by enhancing the capacity of communities to withstand environmental challenges such as floods and cyclones, thereby reducing vulnerability to climate-related disasters (Firdaus & Arkananta, 2024). Additionally, it creates green jobs, which are essential for promoting sustainable economic growth and providing employment opportunities within local communities (Yu et al., 2021). Moreover, CF supports sustainable energy initiatives, which not only reduce carbon footprints but also enhance energy security and resilience (Wang et al., 2024). Another key benefit is the enhancement of biodiversity protection, as CF backs projects that restore ecosystems and safeguard habitats for native species, addressing critical conservation needs (Essl et al., 2018). The majority of the benefits of CF also perform as a way to mitigate some of the environmental harms caused by the construction industry.

3.2.2 Challenges in CF

Despite the benefits the challenges faced while applying and utilising CF in the construction industry are also significant. Table 2 presents such challenges.

Table 2: Challenges encountered in utilising CF

Challenges	Sources
Global (Carbon) Emission Reductions	[1], [2], [3], [4], [5], [6],
Lack of understanding of CF	[1], [2]
Lack of knowledge on CF systems	[1], [5]
Lack of experts	[1], [5]
Lack of Transparency	[2], [3], [5]
Lack of innovation in carbon financial products.	[1], [2], [4], [5]
Lack of Universally recognised carbon market	[1], [3], [4], [5]
Lack of robustness in the existing policies and regulations,	[1], [5]
Lack of legal frameworks.	[1], [5]
Inaccuracies in Carbon Accounting	[2], [3], [5]
Difficulties in integration with Other Policies	[2], [3], [5]
Sectoral Fragmentation	[2], [4]
Price volatility	[2], [5]

(1-Liu et al., 2015; 2- Parenteau & Cao, 2016; 3- Wu et al., 2022; 4-Wang et al., 2019; 5- Lo, 2016)

A significant issue is the lack of understanding of CF (Liu et al., 2015), coupled with insufficient knowledge about CF systems and their operations (Lo, 2016). This knowledge gap extends to both financial institutions and enterprises, limiting their ability to fully engage in carbon financing initiatives (Liu et al., 2015). Despite the significant knowledge on CF in many Western countries, some nations, including China, have a more limited understanding of establishing and developing a comprehensive carbon financial system even by 2019 (Zhou & Li, 2019). Furthermore, the shortage of experts in CF (Lo, 2016), has reduced its popularity among the public and within industries. The inadequacy of existing policies, regulations, and legal frameworks further exacerbates the challenges faced by CF, as these frameworks are often not robust enough to support CF adequately (Zhou & Li, 2019). Chinese literature including Zhou and Li (2019) highlighted the absence of a nationally unified carbon trading platform as another significant hurdle. For the construction sector, a unified platform could streamline the process of acquiring carbon credits, making it easier for companies to offset emissions and invest in greener technologies.

3.2.3 Final Framework

Based on the findings of the study, a comprehensive final framework has been developed, encapsulating the key insights and outcomes derived from the research. This framework serves as a visual synthesis integrating the major findings, highlighting both the benefits and challenges of carbon financing, along with the classification of its financial instruments. As illustrated in Figure 3 the framework provides a structured representation of how carbon finance operates, offering a clear and concise overview of its benefits, limitations, and strategic mechanisms.

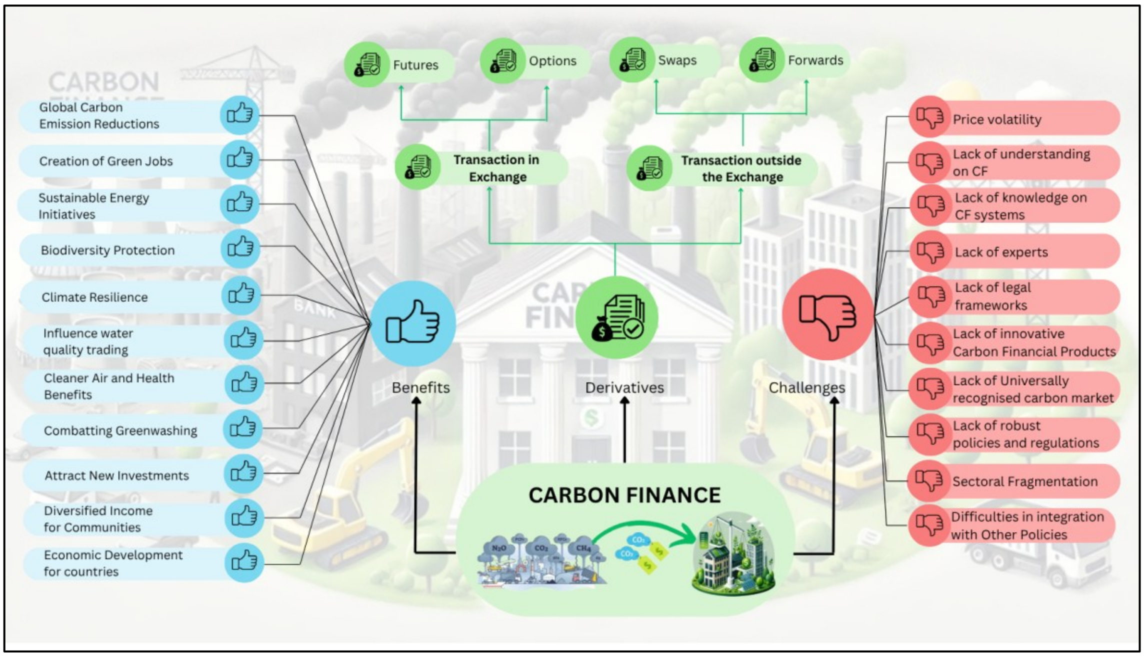

Figure 3: Final framework

Figure 3 presents a comprehensive visual framework of Carbon Finance, organising its key components into three interconnected segments: derivatives, benefits, and challenges. At the centre lies the core concept of "Carbon Finance," symbolised by a gradient illustration that contrasts pollution from industrial. Furthermore, the top section categorises carbon finance derivatives into two transaction types: those occurring outside the exchange (swaps and forwards) and those within exchange markets (options and futures), clearly showing the structural division in financial instruments. On the right, the benefits of carbon finance are listed within a green bubble, emphasising environmental, economic, and institutional gains such as emission reductions, creation of green jobs, sustainable energy initiatives, and enhanced international cooperation. Opposite this, the left section highlights the challenges, including a lack of expertise, transparency, legal frameworks, and policy integration, as well as issues like price volatility and sectoral fragmentation. Together, the image effectively illustrates how carbon finance operates at the intersection of environmental goals, market mechanisms, and systemic barriers, offering a clear and structured understanding of its multifaceted impact.

4. CONCLUSION AND RECOMMENDATIONS

CF is an emerging and largely underexplored area within the context of sustainable construction, offering innovative financial mechanisms that could significantly reduce the environmental footprint of the construction industry. Despite its immense promise, CF remains a hardly touched concept in the construction sector. Hence, this study has explored the critical role of CF in sustainable construction by introducing financial solutions to reduce GHG emissions. This paper contributes to the body of knowledge by providing an in-depth exploration of CF within the construction industry. It offers a comprehensive definition of CF specific to construction while emphasising the CF instruments that can be utilised. The paper also examines the geographical distribution of CF research, revealing the disparity between developed and developing countries.

Additionally, the paper discusses the challenges and benefits of CF, while highlighting its potential to drive sustainable construction practices when applied effectively.

Building on these insights, this study serves as a blueprint for integrating CF into construction practices. By addressing the current challenges and implementing the presented recommendations, the construction industry can move towards a more sustainable future where CF becomes an essential component of its sustainability strategy. This groundwork sets the stage for CF to be a cornerstone of sustainable construction. To achieve this, the study recommends that industry practitioners take several key actions. First, stakeholders, including policymakers, construction firms, and financial institutions should be educated about the benefits, markets, and systems of CF through targeted training programs and workshops. Second, robust policies and regulations must be developed to support CF initiatives, including a clear and universal set of guidelines. Third, utilisation of CF instruments should be encouraged, and new derivatives should be developed to cater to the evolving needs of the construction market. Finally, the creation of a nationally or regionally unified and recognised carbon trading platform is essential to streamline processes and enhance transparency.

Future research could focus on developing sector-specific carbon finance models tailored to the construction industry's unique emissions profile. Additionally, exploring digital tools, including blockchain to enhance transparency and accuracy in carbon accounting is vital. Finally, studies should assess stakeholder knowledge gaps and propose targeted capacity-building initiatives to support the adoption of carbon finance within the sector. Research should continue to explore the interplay between CF and other sustainability initiatives to create a holistic approach to reducing the environmental impact of the construction industry.

5. ACKNOWLEDGEMENT

The authors greatly acknowledge the financial support provided by the Senate Research Committee of the University of Moratuwa under the Grant SRC/LT/2024/12.

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