

Review

Analysis of Carbon Markets and Offset Alternatives in Compliance and Voluntary Schemes to Commercialise Colombian Neutral Coal

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ABSTRACT

This study examines the opportunities in the international carbon market to commercialise coal offsets from the forest economy for compliance schemes and the voluntary market within carbon-neutral and economic diversification strategies using Colombia as a case study due to the importance of coal for the country's economy and its position as a producer. Consideration is given to opportunities in the international carbon markets that can serve as an instrument to decrease global greenhouse emissions. In recent years, the two modalities (compliance and voluntary) of carbon markets have been growing. To the extent that more drastic policies are generated against emissions and the price of credits and/or offsets, the market price of a credit is above US\$20. It is estimated that credits based on nature and generate co-benefits will have the greatest commercialisation potential. In this regard, Colombia has multiple possibilities that could generate a competitive advantage when connected with the commercialisation of carbon. Country-level analyses indicate that the Colombian neutral coal industry has great potential among the regions and countries studied when considering the objectives of the established emissions trading scheme, which in most cases includes the electricity generating sector with a maximum of compensation. Conservatively, this could generate demand for Colombian neutral coal of 5%–10% of the credits and/or required offsets. In the voluntary market, the expectations are positive since many companies that use coal as an input and/or that rely on emission reduction objectives could opt for this strategy to enjoy the co-benefits that this innovative way of marketing coal offers. Colombian carbon neutrality has potential both in the voluntary and regulated carbon markets; efforts could start in the voluntary market and then carry out specific negotiations with countries that have a regulated market. In addition, including projects based on nature, especially reforestation and REDD, will be very beneficial since this sector is expected to experience the greatest growth in the creation of bonds. In

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addition, with the new rules of the COP26, there will be greater security and certainty in integrity and accounting issues, will be positive for the carbon neutral and economic diversification strategy. Furthermore, how the agreements are implemented to identify opportunities and strategies in their implementation should also be monitored. These elements will be fundamental in the analysis of carbon neutrality strategies in Colombia.

KEYWORDS: compliance carbon market; voluntary carbon market; offsets; Colombian coal

INTRODUCTION

International carbon markets are considered an important instrument for reducing global greenhouse gas (GHG) emissions cost effectively. The Paris Agreement in Article 6 recognised the importance of these markets, establishing a framework that accounts for rules, creates a new mechanism, and uses international trading emission allowances to facilitate emissions reduction targets for countries and companies [1].

Global carbon markets show different trends [2]: (i) Carbon prices are rising across different regions, both in compliance (through which regulated entities obtain and surrender emissions permits (allowances) or offsets to meet predetermined regulatory targets) and voluntary markets (which allow carbon emitters to offset their unavoidable emissions by purchasing carbon credits emitted by projects targeted at removing or reducing GHG from the atmosphere), generating incentives for countries and companies to invest in technologies or offsets to decrease GHG emissions. (ii) Greater climate goals increase the relevance of emission trading, and different countries and regions have committed to targets for reducing GHG emissions for the coming decades, which strengthens carbon markets as an instrument to trade and apply cleaner technologies and to benefit the economy and the environment by reducing the externalities of pollution. (iii) Financing of carbon trading. This mechanism offers both green, credible, and good returns that are fundamental for investors that allows them to access and understand the importance of the cost of pollution, increasing sustainability and reducing environmental problems. (iv) Markets must be both green and socially just, which presents an opportunity for governments to drive support and investments to help fund the transition to net zero. These trends are important for determining how carbon markets offer different alternatives to offset emissions as a strategy to achieve an adequate transition in the shift and substitution of fossil fuels.

Carbon regulation has generated different mechanisms, such as price mechanisms, emissions reduction incentives, carbon offsets, and investment in technologies to reduce emissions. This includes the application of carbon removal technologies through nature-based solutions that use ecosystems, such as forests, mangroves, kelp beds, and

soils that naturally sequester or capture CO₂, and mechanical solutions that remove CO₂ from air or the ocean with direct capture technologies that use machines that create other carbon-based materials, including plastics, carbon-embedded cement, and rocks buried deep underground. Both alternatives can generate carbon offsets to be held, sold, and traded on exchanges to help compensate for carbon emissions occurring elsewhere. Different public and private organisations want to purchase verified carbon offset credits to reduce their overall emissions [3].

Offsets can be divided into two categories [4–6]: (i) Avoidance offsets are generated by activities that reduce future emissions through prevention, such as by building wind farms instead of new natural gas energy plants; in general, carbon markets can develop strategies to provide financial incentives to reduce emissions. (ii) Removal/sequestration offsets, such as those in forestry, which represents 40% of all offsets registered, or by mechanical removal with barriers, such as those related to materials and energy requirements and costs.

Compliance carbon markets aim to determine carbon price by laws or regulations that control the supply of permits, which are then distributed by national, regional, and global regimes. These permits are then traded within a controlled emissions trading scheme (ETS), which provides economic incentives to emitting organisations to reduce their carbon footprint [7]. Studies on compliance markets have analysed a variety of approaches, including the following:

- Protection of specific areas through this mechanism. Bousfield et al. [8] analysed whether it is feasible to use carbon payments to protect Amazonian forests by determining cost-effective opportunities to safeguard large tracts of the Amazon rainforest. Shilland et al. [9] studied the possibility of using seagrass meadows to develop payments for ecosystem services projects, establishing the importance of building community capacity in the context of technical and marketing requirements. Jayasuriya et al. [10] evaluated the Riparian Management Zone through three scenarios, indicating that a protocol for compensating landowners with large forest holdings of carbon offsets provides an opportunity to generate positive net revenues and is economically viable.
- Analysis of projects to reduce emissions from deforestation and forest degradation (REDD+). Köhl et al. [11] evaluated the trade-offs between the costs and revenue of a REDD+, measure, report, and verify (MRV) system by conducting a simulation study focused on varying forest degradation intensities in natural forests and recommended that the MRV design be optimised to meet both accuracy and cost requirements. Boer [12] evaluated the development of REDD+ market institutions in Indonesia and determined that government agencies at multiple levels can play a pivotal role in integrating REDD+ market activities within a supportive regime of forest and land management. Aziz et al. [13] studied the possibilities of Malaysian mangrove forests in this type of

project and identified operational strategies and improvements in social-ecological outcomes for forests and their diverse stakeholders. Vijge et al. [14] analysed the possible consequences of REDD+ in seven countries and found that carbonisation and centralization of forest governance are possible outcomes that provide different benefits.

- Application and effects of compliance carbon markets in the productive sector. Junming et al. [15] evaluated the adverse side effects of a regional carbon emission trading program in China on local air pollution at the firm level, suggesting that the direction of spillovers from climate policies is context specific, i.e., depends on the stringency and instrument choice of existing environmental policies. Rong and Haogi [16] analysed the impacts of the benchmark designs of China's ETS by using plant-level data and determined that auction revenue can provide sufficient funds to accelerate China's low-carbon transformation and improve social welfare. Genovese [17] studied the interaction between domestic regulation and decisions related to international climate negotiations at the firm level and found that financial markets carefully follow international climate negotiations and reward regulated firms based on the outcome of UNFCCC decisions and highlighted the perils of privately supported policies for the effectiveness of international public good provision. Shuo et al. [18] designed a dynamic programming model in search of optimal emissions trading and investment decisions under stochastic demand following an emission trading policy, defining that the firm should invest only if the investment cost per unit of abatement effort is less than a certain threshold.
- The effects of compliance carbon markets in the electrical sector and the use of renewable energy. Borozan et al. [19] analysed the electricity sector of eight European countries and found that renewable generation targets vary between the countries; however, the region is committed to electricity sector decarbonisation and digitalisation in the future, where the carbon market will play an important role in the transition. Jingyan and Artie [20] examined the evolving green financial system sponsored by both public and private institutions, including carbon trading entities, determining the potential of scaling up the development of renewable energy by adequately managing and sharing key risks while allocating substantial funding to renewable energy projects, especially by compliance with the carbon market. Weiss et al. [21] designed a model that included electricity supply, CO₂ emissions, consumer costs, and security of supply and emphasised the importance of understanding the interplay of policies and market players to effectively achieve decarbonisation goals and the need for a strategic reserve to ensure compliance with the legal security of supply criteria.

These studies show the importance of compliance with the carbon market at the macro and micro levels and how policymakers and

managers make decisions to reduce carbon emissions according to targets established through different strategies and mechanisms promoted by carbon markets. However, these studies have neither analysed the possibility of commercialising neutral fossil fuels through offsets that promote natural conservation nor investigated how countries that must import fossil fuels to guarantee their energy security could use these mechanisms or strategies in the energy transition process.

Voluntary carbon markets, where companies and individuals choose to offset their emissions, are not legally mandated. Organisations and individuals could be motivated by a desire to offset longer-term climate risks or by ethical or other reasons. Because carbon credits in voluntary markets are not administered by a specific government, they are accessible to every sector worldwide, in contrast to compliance markets [7]. Researchers on voluntary carbon markets have worked in the following areas:

- Interest, perception, and implementation of the voluntary carbon markets in business. Lu et al. [22] evaluated the role of voluntary action plans in reducing CO₂ emissions in Japanese industries and found that this mechanism is ineffective in sectors with low market concentrations and that the energy intensity targets of the mechanism did not lead to a significant reduction in CO₂ emissions. Jiang et al. [23] analysed the value relevance of voluntary corporate carbon disclosure using firms in the US and BRIC countries and found that firms with greater carbon disclosure have higher firm values and the positive association between firm value and voluntary carbon disclosure is stronger in developing countries. Alsaifi et al. [24] examined market reactions to voluntary carbon disclosure in the context of English-speaking industries and determined that investors perceive these markets to be associated with climate-related environmental investments, which represent costs that are not perceived to be offset by tangible benefits and that weaken competitive advantage.
- The relationship between voluntary carbon markets and renewable energy. Yue et al. [25] evaluated the role of renewable energy in reducing carbon damage in a panel of five selected island economies for 2001–2020 and found that promoting offsets by renewable energy is important for reducing the cost of carbon emissions and making the economies green and clean. Zhang et al. [26] analysed the impact of renewable energy investment on carbon emissions in China, establishing the existence, direction, and intensity of the impact of renewable energy investment on carbon emissions and where it is important to advance investments in renewable energy through different mechanisms, such as voluntary carbon markets or offset mechanisms. Herbes et al. [27] compared markets in the UK, Germany, France, and Italy to analyse connections between structural factors in the respective markets, especially policy frameworks, and dominant product strategies in each market related to renewable energy and

decreasing CO₂ emissions. They determined that none of the four countries had successfully established a policy framework that fosters the development of a voluntary market for green electricity that was capable of driving the expansion of renewables.

- Voluntary carbon markets related to tariffs and consumer behaviour. Tao et al. [28] explored the influencing mechanism of Chinese consumers' willingness to offset and found that high-carbon consumers, who are generally more knowledgeable about carbon offsetting, are more confident in taking action and are willing to pay more for carbon offsetting. Gunter et al. [29] examined how the announcement of an organisational carbon offset programme affects consumption in a CO₂-intensive daily activities and suggested that carbon offset programmes may increase resource use. Mac Donald and Eyre [30] analysed green electricity tariffs related to offset and carbon markets, determining that high competition in energy markets is a key driver of green tariff success, with countries where consumers switched regularly being more likely to have high enrolment.
- Voluntary carbon markets in specific sectors such as aviation or recreation. Ritchie et al. [31] evaluated the effectiveness of different communication messages to increase voluntary purchasing of carbon offsets by air passengers and found that air passengers prefer carbon offset schemes to fund accredited local programs (as opposed to international programs) that are effective in mitigating emissions. Heintzman [32] determined that certain practices may contribute to the growth of voluntary carbon offset sales in the outdoor recreation industry, such as marketing to people with certain characteristics (e.g., younger age, higher education, low carbon diet, appreciate participating in outdoor activities, and awareness of these programs), addressing barriers that adversely affect current offset schemes, considering both willingness to pay when setting offset prices and alternative explanations of individuals the greatest volume of CO₂ and ensuring a positive purchase situation. Shiyuan et al. [33] developed a theoretical model to investigate airlines' incentives to collaborate on offset purchases and the potential mechanisms and corresponding market/welfare implications. They found that airlines do not have an incentive to cooperate in offset purchases in the Chicago Climate Exchange market but may be willing to form alliances in the over-the-counter (OTC) market.

These studies have produced important findings on the application of the voluntary carbon market for businesses and the challenges that firms face in determining strategies to apply offsets that contribute to reducing environmental problems and CO₂ emissions. However, the voluntary carbon market could offer possibilities for fossil fuels by commercialising offsets. For this reason, it is important to analyse this market because it could support neutral fossil fuels in the energy transition, which could

help countries and producers of fossil fuels comply with their commitments to climate change and sustainability.

This background illustrates the limitations to analysing carbon markets related to the possibilities of fossil fuels, such as coal in energy transition, from perspective of commercialising offsets, which is fundamental for countries that depend economically on fossil fuels, as an alternative to. To reduce environmental pollution and promote sustainability, it is important to analyse this strategy to determine its possibilities and limitations. Hence, this study examines opportunities in the international carbon market to commercialise Colombian coal offsets from the forest economy for compliance schemes and in the voluntary market within carbon neutral and economic diversification strategies as examples or case studies. Colombia is an emerging economy that has a high dependence on the export of coal in its trade balance. It was the third largest exporter of coal, which is Colombia's main mining export, in the world in 2021. Coal accounts for 56.1% of the contribution of the mining sector to gross domestic product and 0.74% of the sector's contribution to the national gross domestic product. In productive regions, the coal industry generates approximately 130,000 jobs (75% in small and medium enterprises), and US\$500 million in annual royalties (accounting for 88% of the royalties of the mining sector). Taxes are then used for investments to promote sustainable development in different regions of the country. Moreover, the strategic plan of this sector seeks to promote competitiveness, legality, security, best practices, adaptation, transition, diversification, and institutional strengthening [34].

Thus, the primary purpose of this study is to analyse opportunities in the international carbon market to commercialise coal offsets from the forest economy for compliance schemes and the voluntary market within carbon-neutral and economic diversification strategies using Colombia as case study due to the importance of coal for its economy and its position as a coal producer. This study can provide valuable help in creating strategies and inputs for policies that will contribute to sustainable development of fossil fuel production in the transition period and create opportunities to mitigate environmental problems and conserve natural landscapes and biodiversity. With this background, our study seeks to answer the following research questions: Question 1: How do compliance and voluntary carbon markets operate in Colombia, and what are the possibilities for commercialising Colombian offset coal? and Question 2: What is the potential demand for Colombian coal offset from the Climate Neutral Coal Strategy?

To answer these questions, a variety of methods were used, including a review and analysis of compliance and voluntary markets, and interest in productive sector of offsets. With these results, the potential demand for Colombian coal offsets is determined, which could aid producers, policymakers, and decisionmakers in leveraging new ways to commercialise coal using offsets, ultimately to support environmental

protection and reduce environmental problems. The rest of the paper is structured as follows. Section 2 (METHODS) highlights the methods and data used in this study. Section 3 (RESULTS AND DISCUSSION) shows the results and presents the discussion and policy implications. Section 4 (CONCLUSIONS) presents the conclusion.

METHODS

Several methods were used in this study to determine opportunities for coal offsets according to compliance or voluntary carbon markets, considering the requirements and operations of these markets within Colombia's carbon neutrality and economic diversification strategies.

Compliance Carbon Market

For the compliance carbon market, we identify countries that could receive reduction certificates/offsets from the Colombian coal-identifying carbon-pricing mechanism (tax or emission trading schemes). The process enabled us to carry out offsets under the established price mechanisms by participating in the mechanism of the coal consumer/energy sector, among others. We reviewed different documents through dynamic consultations on the web for equations and web scraping using keywords related to compliance schemes of carbon markets and verified the quality of the documents and data. We also consulted with key stakeholders who have experience in compliance schemes. With these results, the possibilities for offsetting coal in the countries evaluated that could meet their obligations according to ETS are analysed.

Voluntary Carbon Market

In the case of the voluntary carbon market, the main companies that buy and use (not intermediaries) thermal coal and coke offsets to demonstrate their commitment to decreasing GHG emissions are identified. The features and trends of this market are determined in the industrial sector using a mixed method that includes a collection of secondary information to identify the main companies that work under voluntary market arrangements using equations with keywords and including the information in a matrix that identifies the main features and opportunities of the main coal-consuming companies.

Potential Demand for Colombian Coal Offset

In this stage, and accounting for the results of the previous analysis, the potential demand for Colombian coal offsets following the Climate Neutral Coal Strategy initiative is determined. Article 6 of the Paris Agreement and the results of the last Conference of the Parties (COP 26) are considered, using projections and comparisons that allow us to determine, according to the baseline, the possibility of applying this mechanism to promote coal offsets. Moreover, it used the following databases to define different

industries interested in this market, such as Science-Based Targets and Bloomberg.

RESULTS AND DISCUSSION

In this section, the main results of the study are shown regarding the possibility of commercialising coal offset as a strategy to respond to the energy transition and to promote natural solutions and forest or reforestation processes in a biodiverse country such as Colombia.

Results for the Compliance Market for Coal Offset

Signed in 2016, the Paris Agreement marked a new era for carbon markets in which all countries contribute to global mitigation efforts. Countries frequently express their commitments at the national level, which affords the necessary flexibility so that they can contribute transparently and monitor their progress. In addition, each of the interest groups may sell and buy emission reduction certificates in a regulated or voluntary manner, considering the guidelines of Article 6 of the Paris Agreement, which provides the option for countries to generate and market mitigation results. At the international level, countries participate in mechanisms generated by governments and collaborations with noncommercial strategies. Figure 1 illustrates carbon market trends based on [35].

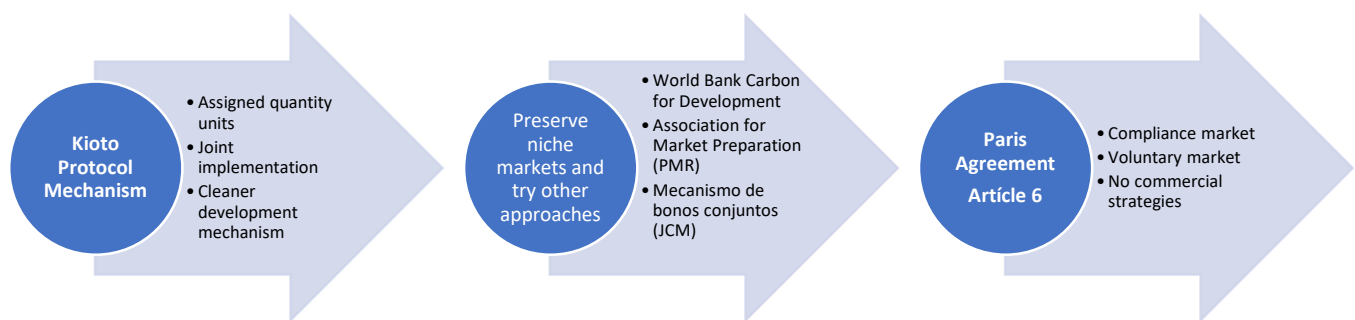


Figure 1. Carbon market trends. Source: Based on [35].

According to [36] in the Refinitiv report (2020), carbon markets are estimated to have grown by close to 20% (compared to 2017), which is equivalent to 229 billion euros based on transactions and carbon prices. Since the signing of the Paris Agreement, there is evidence that the regulated market has grown approximately fivefold since 2017, accounting for the limits established for carbon generation. Moreover, countries that signed the Paris Agreement should create mechanisms for clean projects such as green energy or carbon capture methods and technical innovations such as mitigation activities or taxes from climate

change perspectives. These efforts could catalyse environmentally friendly companies to fulfil the commitments of the Paris Agreement [37,38]. Furthermore, new and innovative policies to promote energy transition could be designed to leverage carbon markets based on the promotion of cleaner technologies, conservation of the environment, and offset possibilities from Article 6 of the Paris Agreement.

According to [39], regulated carbon markets take six key elements into account: governance and accounting, scope and eligibility, environmental integrity, monitoring, reporting and verification, ensuring sustainable development, and links with other carbon pricing instruments. In the regulated carbon market, the leading mechanism is clean development (CDM), which was issued by the UNFCCC based on the database developed by [38], and the trends and dynamics of this mechanism. The total number of registered CDM projects for 2021 is 7857, which comprises 93% of the 8419 active CDM projects. Seventeen projects are not in force because their certifications have already fulfilled the estimated reduction or validity period established and only 561 projects are still in the validation process. This has resulted in the issuance of 2096 million CERs, of which 1485 million were generated between 2008 and 2012 and approximately 611 million between 2013 and 2020. The CDM projects that have prevailed are those of renewable energy followed by the reduction of CH₄, cement, and coal mining. This is a promising sign that the neutral coal project has potential through this mechanism, which could be an alternative for countries that produce fossil fuels.

Regarding the location of the CDM, the Asia and Pacific region has the highest share of projects and CER emission certificates at greater than 80%, followed by Latin America with approximately 13%, indicating that these two regions have been fundamental in the development of this mechanism. With respect to countries in Asia, China stands out (with 56% of projects and 70% of credits), followed by India (with 29% of projects and 18% of credits). In Latin America, Brazil leads (with 35% of projects and 39% of credits), followed by Mexico (with 18% of projects and 15% of credits), and Chile (with 10% of projects and credits). The average costs of CERs range between US\$0.4 for open CERs or those that do not have exclusivity in their sale or platform, and US\$1–5 for CERs through the VC platform [40].

Most of the CERs (57.6%) generated from the CDM established by the Kyoto Protocol have been issued for projects in China and are mainly concentrated in the following eight countries in order of importance: India (11%), Korea (9%), Brazil (5%), Mexico (2%), and Chile, Afghanistan, and Vietnam (less than 1%). The countries that buy the most CERs are, in order of importance, the United Kingdom, Switzerland, Holland, Japan, Sweden, Germany, France, Spain, Italy, France, Austria, Denmark, and Finland. This indicates that European countries have mostly used this mechanism to mitigate their GHG emissions by compensation through the CDM. Outside of Europe, New Zealand is the country most interested in buying CERs.

Emission trading schemes have become fundamental to countries' climate objectives based on the requirements of the Paris Agreement. According to [41], it is estimated that 54% of the jurisdictions that represent world GDP use this type of mechanism, 16% of global GHG emissions are covered by an ETS, and almost one-third of the world's population lives with a current ETS. Table 1 shows the geographical distribution of this mechanism.

Table 1. Distribution of ETSs worldwide.

Jurisdiction	Localisation
Supranational (1)	European Union, Iceland, Liechtenstein, and Norway
Countries (8)	China, Germany, Kazakhstan, Mexico, New Zealand, Korea, Switzerland, and the United Kingdom
Provinces and states (18)	California, Connecticut, Delaware, Fujian, Guangdong, Hubei, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Nova Scotia, Québec, Rhode Island, Saitama Prefecture, Vermont, and Virginia
Cities (6)	Beijing, Chongqing, Shanghai, Shenzhen, Tianjin, and Tokyo

Source: Based on [42].

Regarding compensation in carbon neutral and economic diversification strategy, the following must be considered. (i) Countries that do not accept compensation, such as Israel and Europe, are unable to use this strategy and must seek alternatives. (ii) The jurisdictions that accept forest sector compensation are Korea, Saitama, California, the Regional Greenhouse Gas Initiative (RGGI), Quebec, and Tokyo (which do not include the forest sector). (iii) The jurisdictions that are developing the compensation mechanism are China, Taiwan, Nova Scotia, Mexico, Chile, and Colombia. (iv) The jurisdictions that have not defined compensation mechanisms are India, Turkey, Massachusetts, and Brazil. This implies that, from the perspective of compensation, the strategy has potential, especially in Korea, Saitama, California, the RGGI, and Quebec, as long as the projects follow established methodologies and processes to obtain them. In addition, the compensation data for offsets are very limited, and several countries prefer not to accept them. Table 2 shows the main features of offsets in the countries studied and recommendations to commercialise neutral coal, indicating greater possibilities in countries that use coal to produce electricity and have flexible mechanisms.

Table 2. Analysis of the main features of offsets in the context of carbon neutrality and economic diversification strategies.

Country and instrument	Offsets and recommendations
China ETS—in force	5% of verified emissions. Offsets can be acquired up to 20%. The forestry sector follows methodologies established by the government and at the international level. The limit of offsets has not yet been defined. Since the market is flexible, negotiations can be made with generators to cover the percent of offsets with the strategy and/or acquisition of reduction certificates.
Korea ETS—in force	5% of emissions. Auction (90%) and free allocation of 100%. 38 million international offsets can be purchased, following the methods established by the government and can accept offsets from forestry projects. By having this ETS with free allocation and the possibility of buying credits internationally and covering companies that use thermal coal in the short term, it is possible to negotiate with this country due to the co-benefits offered by the strategy.
Taiwan ETS—under consideration	To define auction and free assignment. The offsets are under study. Being under study and wanting to be completed with a price scheme, the possibility of marketing it could be analysed with specific sectors as a strategy to respond when the ETS is in force.
Japan ETS in force (Tokyo y Saitama)	Includes so-called low carbon certifications. Saitama accepts forest offsets that must be validated by entities authorised by regional governments. The possibility of offering carbon neutrality in the regional ETS could be explored. How the national ETS is developed to assess the possibilities can be analysed in the future.
Turkey ETS—under consideration	Evidence of emission reduction. The offset mechanism is under study. The potential market could be reviewed considering that the possibility of acquiring credits and/or offsets in sectors of interest will begin to be regulated in the future.
India Pilot of ETS	It does not have established offset mechanisms. It allows the purchase of issuance credits, which are key to the strategy while the ETS guidelines are defined.
Israel Taxes	Undefined. As it does not have ETS, the possibility of a price strategy for the sale of carbon neutrality should be reviewed.
European Union ETS—in force	Free allocation by sectors and auction period certificates reserve. They are in the reduction period or not in use of the offsets. Offsets are in the process of being reduced, the possibility of reviewing the strategy in free assignments or sectors where technological change is slower and that use coal could be analysed.
USA ETS—Regional in force	Free allocation by auction. Forest sector offsets. Limits in some ETS of 3% are validated by the system. There are possibilities of taking into account that forest offsets are accepted, and their coverage is the electricity sector.
Canada ETS—Regional in force	Free allocation by auction and offset limits. It has potential by including the electrical and manufacturing sector that uses coal and allowing offsets with limits.

Table 2. Cont.

Country and instrument	Offsets and recommendations
Mexico ETS—in force	They are under development with a maximum of 10%. Free assignments are estimated for various sectors and the offset system is being studied. This ETS includes sectors that use thermal coal and allows compensation; it would have potential by reviewing directly with companies or through free assignments with the government.
Brazil ETS—under consideration	Certificates of emission through biofuels. No compensation mechanism has been defined. The ETS is under consideration, carbon neutrality could be analysed through the mechanisms used for biofuels.
Chile ETS—under consideration and taxes	The offset regulation is being studied, and the approval of an offset scheme that also applies to taxes is expected. This country is in the regulation stage with the greatest advance on the issue of taxes and compensation possibilities, which implies analysing how the strategy would work on the issue of prices and/or offsets based on its regulation.
Colombia ETS—under development and taxes	Auction, allowances and offset possibilities. Giving priority to forestry issues could support the strategy by having offsets from this sector that are attractive in the carbon market for future commercialisation.

Results for the Voluntary Market for Coal Offset

According to their interests or as part of the compliance market, the voluntary carbon market is characterised by trade between buyers and sellers. The carbon offsets that are generated from projects that reduce emissions and are measured in metric tons of carbon dioxide equivalents (tCO_{2eq}) that are constituted in carbon credits, emissions reduction certificates, or carbon offsets, where each is equivalent to one ton of CO_{2eq}. A series of rules and procedures are followed to issue the respective credits, which need buyers who can be end users, retailers, or brokers who resell or charge a fee to find an end buyer. Currently, this market has a demand of approximately 95 MtCO_{2eq}/year, which represents 0.2% of global GHG emissions and is present in 83 countries [41,42]. Within the voluntary carbon market, the most prominent category of projects is related to forestry and land use issues that involve the management of forests, soils, grasslands, and other types of land to avoid the release of carbon and/or increase the amount of carbon absorbed by the earth. From 2016 to 2020, the number of projects grew to 187, achieving a reduction of 95.3 MtCO_{2eq}. During this period, an average of approximately 31 projects were approved per year, of which three projects per year belong to the REDD+ typology on average [43,44]. These results indicate that neutral coal could use REDD+ projects, especially in countries with natural resources where the conservation of forest areas is fundamental.

Regarding the use of carbon credits and/or offsets for the countries covered by this study, those with the highest number of offsets and projects are the US, followed by China and India. In the US, offsets and/or credits are registered in ACR and CAR, while in the other countries, VERRA (VCS) and GOLD predominate (see Table 3). Guatemala, Canada, and the US have the highest compensation in the forest category, while India concentrates its compensation on renewable energies (see Table 4). These results show the great potential that Colombia has in a voluntary market where the demand for these credits can be consolidated with other benefits, especially in the commercialisation of the carbon neutral strategy and economic diversification. These results show that the sale and/or commercialisation of credits or certificates in the voluntary market also depends on the entity in which it is registered, considering that VERRA and Gold obtain better prices and greater demand.

Table 3. Data on the voluntary carbon market by country and standard.

Country where project is located	Total number of projects	Number of credits/offsets by standard				Total of used or retired credits or offsets
		VCS	ACR	CAR	GOLD	
USA	1142	27,994,188	372,866,787	162,048,908	77,121	372,866,787
India	1025	165,232,196	186,177,180	-	20,944,984	186,177,180
China	673	96,461,765	118,933,621	-	22,471,856	118,933,621
Brazil	146	63,354,762	69,400,143	-	1,443,195	69,400,143
Tukey	454	18,704,509	59,570,712	-	40,866,203	59,570,712
European Union	63	11,590,356	13,252,602	-	1,662,246	13,252,602
Korea	12	12,674,530	12,674,530	-	-	12,674,530
Guatemala	13	5,847,107	6,926,732	-	1,079,625	6,926,732
Canada	14	5,238,969	5,381,004	-	68,429	5,381,004
Taiwan	8	109,191	5,251,440	-	5,142,249	5,251,440
Chile	30	2,381,653	4,650,054	-	2,268,401	4,650,054
Mexico	90	2,155,787	2,603,408	274,901	172,720	2,603,408
Israel	2	16,574	16,574	-	-	16,574
Total	3672	411,761,587	187,422,362	162,323,809	96,197,029	857,704,787

Source: [45].

Table 4. Percentage of projects by category in the carbon market by country.

Country	Percentage of credits/offsets by project type								
	Agriculture	Carbon capture and storage	Chemical process	Forests and land use	Household and community	Manufacturing	Renewable energy	Transport	Waste management
China	-	-	4.6%	7%	6.30%	13.5%	66.8%	-	1.8%
Korea	-	-	-	-	-	95.80%	0.20%	-	4.0%
Taiwan	-	-	-	-	-	-	99.97%	-	0.03%
Israel	-	-	-	-	-	27.80%	-	-	72.2%
Turkey	0.10%	-	-	-	-	0.10%	81.08%	0.02%	18.70%
Mexico	1.10%	-	-	47.90%	20.20%	0.20%	16.55%	-	14.05%
Chile	-	-	-	20.10%	-	-	36.20%	-	43.70%
Brazil	0.30%	-	-	72.80%	0.20%	0.40%	23.08%	0.06%	3.16%
India	0.31%	-	0.22%	0.33%	2.70%	6.10%	90.04%	0.10%	0.20%
Guatemala	-	-	-	78.40%	20.10%	-	1.50%	-	-
European Union	3.72%	-	-	5.73%	-	76.30%	11.45%	-	2.80%
USA	2.70%	5.80%	16.04%	55.80%	-	3.10%	2.70%	0.25%	13.61%
Canada	-	-	1.40%	63.60%	-	34.80%	-	-	0.20%

Source: [45].

The price of carbon credits and/or certificates in the voluntary market depends on different elements, such as the type of project (based on the number of credits or certificates it generates and the interest of buyers in certain categories of projects) and the attributes of the project (which depend on the location, registration, standard, age, co-benefits, and additional impacts, fulfilment of sustainable development objectives, and community development). According to the latest study [42], forestry, land use, and housing and community projects have increased in prices mainly due to the additional benefits and impacts they generate. Likewise, the demand for credits and/or compensation for projects related to renewable energies, energy efficiency, and fuel changes continue to increase, especially in Asia, where the demand is approximately US\$1 per ton. According to Bloomberg, the main buyers of carbon credits between 2017 and 2019 were Delta, Alphabet, Disney, Salesforce, and JPMorgan Chase & Co, who purchased these credits to avoid having to change their processes and to compensate for their emissions [46]. This indicates the importance of reviewing the volatility of the price of carbon credits when commercialising neutral coal to determine the effects on the cost of projects.

To identify potential companies that could be interested in participating in the carbon neutral strategy and economic diversification to offset their emissions, we worked with companies from five sectors in the energy supply chain: construction materials (cement, brick, and glass), iron and steel, food and paper. We took into account that several plants in these sectors use coal or thermal coal in some of their processes according to the International Energy Agency.

To select the companies in each sector according to the countries of interest in the study, the databases of [47–49] were reviewed. Companies that would be interested in buying into the carbon neutral strategy and economic diversification and/or having this type of compensation to meet their sustainability or GHG emissions commitments were considered. Importantly, the companies listed in this report already have experience and/or understand how the voluntary market operates or have internal GHG emissions reduction commitments, which would favour a neutral coal marketing strategy.

Figure 1 shows the number of companies selected by sector that could be interested in participating in carbon neutral and economic diversification initiatives either because they consume coal or have reduction commitments. There is a total of 239 companies, with the highest number concentrated in the energy supply chain, building materials, food, paper, and steel sectors. The principal regions or countries are Europe, the US, India, and Brazil, which coincide with the regions that buy the greatest quantities of coal from Colombia: Europe, Western Asia, and South America (see Figures 2 and 3).

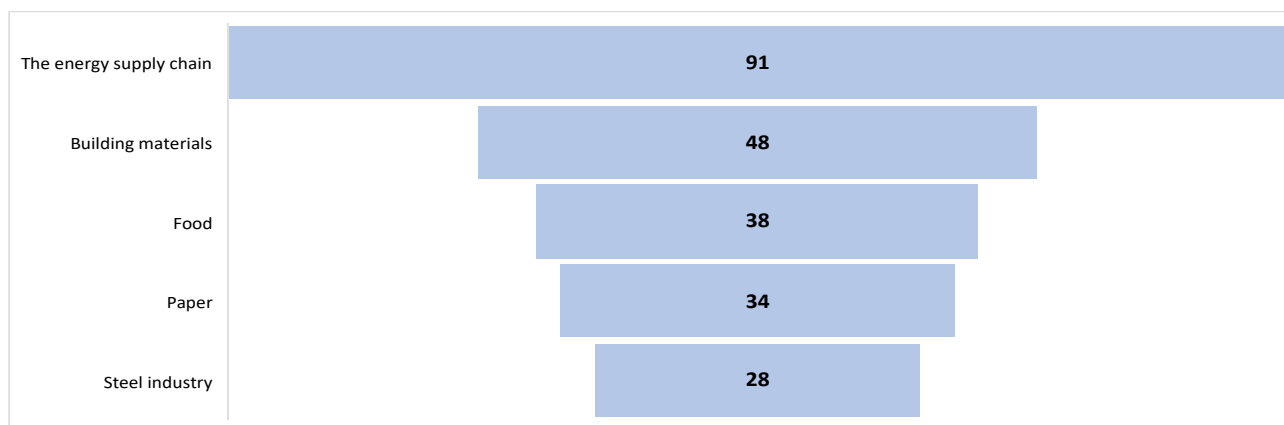


Figure 2. Number of potential companies by industrial sector that could use carbon neutral and economic diversification strategies because they use coal or have reduction commitments. Source: [47–49].

These companies can generate various strategies. (i) In the case of multinationals, projects can be marketed at their headquarters to demonstrate environmental or social responsibility commitments. (ii) For local companies, the purchase or generation of credits could be used as a marketing strategy for the final consumer due to the current trend of generating responsible purchases, export possibilities, etc. (iii) For companies in the energy chain, carbon neutrality and economic diversification strategies could be managed through energy transition processes and/or social responsibility. All these elements are important for this strategy, verifying the business interests that allow win-win strategies for the productive sector through environmentally friendly processes.

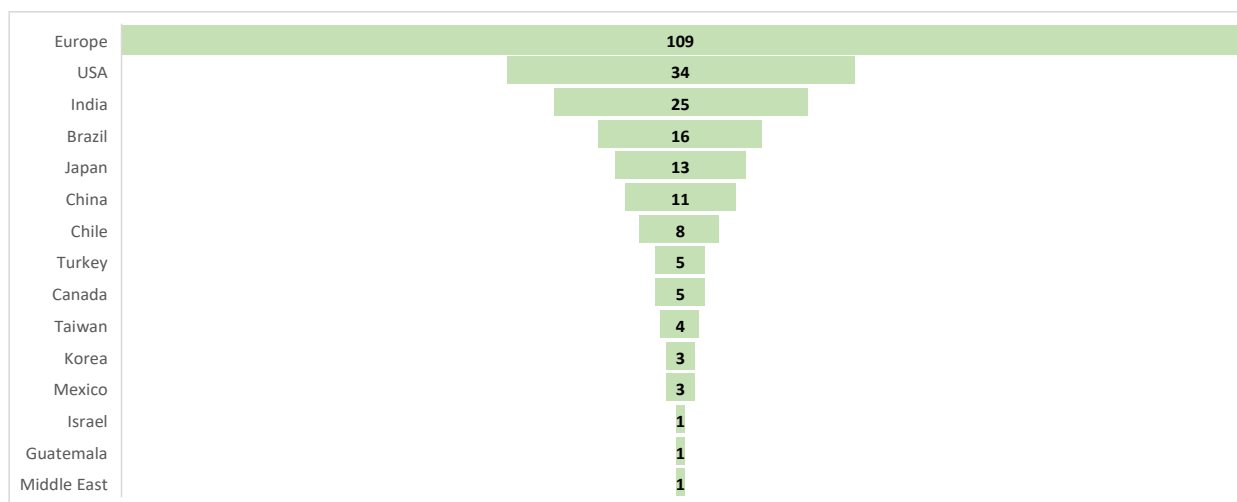


Figure 3. Number of companies by potential countries to offer carbon neutral and economic diversification strategies. Source: [47–49].

Potential Demand for Coal Offset Using Colombia as a Case Study or Example

In recent years, compliance and voluntary carbon markets have been growing. To the extent that more drastic policies are generated against

emissions and the price of credits and/or offsets, this market manages to be above US\$20 by credit. They will continue to grow, especially among companies and governments, with growth rates between 5% and 15%, depending on the type of market. In addition, it is estimated that the credits with the greatest commercialisation potential are those based on nature and that generate co-benefits. In this regard, Colombia has multiple possibilities that, connected with the commercialisation of carbon, could generate a competitive advantage.

The analysis by country shows that there is great potential for neutral coal in the Colombian regions and countries studied, accounting for the objectives of the established ETS, which in most cases include the electricity-generating sector with maximum compensation. This could generate demand for this sector of Colombian neutral coal in a conservative scenario of 5% to 10% of the credits and/or required offsets. In the voluntary market, the expectations are positive because many companies that use coal as an input and/or that are working towards emission reduction objectives could opt for this strategy of marketing coal with its related cobenefits. These elements will be fundamental in the analysis of the carbon neutral strategy in Colombia, and it is important to monitor the trends and policies that may affect the carbon market and that allow defining the changes or new strategies in the commercialisation of the Colombian neutral market.

Another important point in the analysis of the carbon market, both regulated and voluntary, is the typology of projects that are easier to market. For example, carbon credits generated by forestry projects and land use between 2016 and 2018 increased by 264%, while other types of projects grew by 21%, considering that the Intergovernmental Panel on Climate Change (IPCC) has highlighted the importance of “carbon sinks” as a strategy to meet the objectives and agreements of countries and companies. REDD projects that aim to reduce emissions from deforestation and degradation and afforestation and reforestation projects that focus on tree planting are included in this category [50].

Several of the countries that have a mandatory carbon market ETS have specific reduction targets and percentages of bonds and/or compensation that can be purchased either in general or by sector, which could be analysed and used by the country in the commercialisation of carbon neutrality. This is especially the case for ETSS that regulate the generation of electricity, particularly in Asia and Europe, where the possibility of compensation in a conservative scenario is between 2% and 5%. In the case of North America, it is important to have a rapprochement with the regional ETS, as this would increase the potential for commercialising carbon neutrality. With those Latin American countries where ETSS are starting or are under study, it could also work with short- and medium-term expectations. Table 5 shows a description of the compensation potential and recommendations for deploying the strategy by country.

Table 5. Potential trade-offs and recommendations for carbon-neutral strategies and economic diversification by country.

Country	Potential offsets that can be purchased in millions per year (MtCO ₂ e)
China ETS—in force	<p>With hard policies, the potential compensations are: 2021–2025, 48; and 2026–2030, 81.</p> <p>With soft policies, the potential compensations are: 2021–2025, 24; and 2026–2030, 43. It covers electricity generation companies that represent approximately 4 billion tons of CO₂ per year.</p> <p>At the international level, the compensation limit has not been defined. These elements could be analysed in light of the strategy to define possibilities of selling carbon neutrality through the flexibility of the regulated market or in the voluntary market directly with companies.</p>
Korea ETS—in force	<p>Offsets between 5% and 10% can be used against compliance reduction requirements. Limit of 38 million international emission reduction certifications. A use of 1% to 5% of the compensation required by the country could be projected based on the carbon neutral strategy and/or analyse the voluntary market. The ETS of this country is one of the most developed. In the short term, the strategy could have possibilities due to the limit of international compensations it receives, including the electricity generation sector.</p>
Taiwan ETS—under consideration	<p>10% offsets from the electricity sector. The mechanism has not been established because the possibility of the integrated ETS with taxes is being reviewed.</p> <p>The compensation potential could be 0.23 in 2021–2025 and 0.46 in 2026–2030. In this country, because there is currently no ETS, the possibilities of the voluntary market or compensation via taxes could be analysed.</p>
Japan ETS in force (Tokyo and Saitama)	<p>The Saitama ETS allows offsets from the forestry sector. The offset potential this country could acquire is from 0.71 to 0.28 per year and negotiations at the regional level are needed, considering that there is no national ETS. For the deployment of the strategy, it is recommended to approach the regional ETS and/or covered electricity generation companies to review the potential for commercialising carbon neutrality and/or in the other regions to review with the companies the possibilities in the voluntary market.</p>
India, Turkey, and Israel	<p>They do not have ETS. In these countries, the voluntary market could be started while their ETS is institutionalised and it is important to consider the current taxes, co-benefits and possibilities of selling a compensated carbon of approximately 1% to 5% of compensation that may be needed, especially in the productive sector and for electricity generation.</p>
European Union ETS—in force	<p>The ETS is under review. Currently, the EU wants to migrate to zero compensation and there could be potential with excluded sectors or countries with low technological development. While the ETS is being updated, the short-term potential compensation could be between 0.86 to 4.3. For electricity-generating companies, the possibilities in the voluntary market could be analysed considering climate commitments and marketing strategies that evidence social responsibility and/or commitment to the environment.</p>

Table 5. Cont.

Country	Potential offsets that can be purchased in millions per year (MtCO_{2e})
US ETS—Regional in force	Work should be done with the regional ETS since they prioritise the electricity sector and the flexibility they offer in the purchase of offset by emitters could be an advantage for the commercialisation of carbon neutrality. In other states, the possibility of carbon neutrality could be analysed in the volunteer market. In the RGGI ETS, the compensation potential is 1.73, and in the ETS in California, the compensation potential is 1.34.
Canada ETS—Regional in force	Allows offsets, especially for forestry projects. Offset potential could be 1.82 to 3.40. For this reason, the carbon neutral strategy could have possibilities both in the regional ETS and in the voluntary market directly with the electricity-generating companies.
Mexico ETS—in force	Issuers can use emission reduction certificates up to 10% for offset projects to achieve established compliance. Offset potential could be 1.55. As Mexico is still a flexible ETS, carbon neutrality could have a good chance, similar to the voluntary market.
Brazil ETS—under consideration	It is under study. The issue of forest compensation could be reviewed, pending the definition of ETS mechanisms in the future. In Brazil, the strategy could apply to the voluntary market and follow the figure they have for the issue of biofuels to analyse the potential for carbon neutrality.
Chile ETS—under consideration and taxes	It is under definition. It is expected that the ETS will begin to operate in 2023. The offset potential can range between 0.86 and 1.73. The advances in the offset regulation that are under study should be reviewed, and the tax issue could be analysed to verify the possibility of reduction via compensation or possibilities with the voluntary market.
Colombia ETS—under development and taxes	In Colombia, the ETS is under development. However, the issue of taxes, especially for fossil fuels, exists and the ETS allows a 100% offset. There could be an opportunity to design strategy at the national level and/or developing joint forestry projects that meet the needs of the bonds required to implement the strategy.

It is estimated that the voluntary market could be in the range between US\$5 and \$50 billion by 2030, which is equivalent to a 15-fold increase, where multinationals and companies in the energy sector will continue to be potential users of this alternative. This implies that emissions trading will continue to be an alternative due to the flexibility and potential it offers to companies. However, to continue on this path of growth, it is necessary to continue strengthening quality processes in the value chain, project design and implementation, and transparency in the data and indicators that they issue in terms of emission reductions.

The rules established at COP26 offer the necessary framework to avoid double counting and require reports on how countries engage in carbon markets, subject to international review, that countries clarify and quantify their NDCs and that they establish incentives to expand the scope of NDCs over time. Currently, the challenge for the carbon market is that the relevant rules of Article 6 establish operations and applications that

guarantee environmental integrity, which implies that each country provides evidence and manages to structure a solid accounting system [51].

For companies, the agreements reached allow them to be sure that global carbon markets support the trading of emissions reduction certificates or bonds without double counting. It will allow hybrid models for the corresponding adjustments made for transfers between countries, as well as with nonnational actors. It also provides a flexible approach to financing global adaptation through markets and will enable an orderly transition of Kyoto Mechanism activities to Paris-led markets in the mid-2020s [52].

In the analysis of coal offset possibilities, it is important to apply the broad principles proposed by Stern et al. [53] that promote effective climate decisions at the local and regional levels, which are as follows: (i) To analyse and evaluate stakeholders or users' needs or requirements, (ii) to prioritise process over products, (iii) to link or relate information producers and users, (iv) to build and strengthen connections and relationships across disciplines and organisations, (v) to seek and guarantee institutional stability, and (vi) to promote knowledge and research to guarantee design for learning.

Moreover, the possibilities of coal offsets must include the potential of different political strategies to overcome the difficulty of achieving clean production by offsetting or decreasing efforts towards environmental protection in the whole value chain to model carbon offsetting with responsibility, transparency, additionality, monitoring, control, reporting and environmental and social contributions [54].

CONCLUSIONS

From the perspective of the carbon neutral strategy and economic diversification, the possibilities in the regulated carbon market imply that the ETS particularly includes the electricity-generating sector and industries that use thermal coal. The criteria with which it operates include emission limits, the percentage of external emission certificates that can be used to compensate in the international market, market flexibility, and free allocations. Compensations are limited to jurisdictions such as Korea, the Saitama Region, California, and the RGGI. In the case of taxes, the issue of prices and/or their reduction due to compensation could be reviewed, as proposed by Chile, for example, and the proposals that Israel is working on.

By country, due to the flexibility of its markets, allowing compensation and including free assignments, China, Turkey, India, Taiwan, and the Latin American countries could have greater potential for the strategy to the extent that the compensation guidelines are defined. In the case of Korea, which already has a maximum compensation limit, there could be opportunities from the current fuel transition that is being worked on, and in the case of Japan, the possibilities could be analysed with the Joint Credit Mechanism (JCM), which is a bilateral credit compensation mechanism to

encourage low-carbon technologies, green investments and knowledge and develop R&D activities considering their impacts on reducing the ecological footprint and promoting sustainable development [55–57].

In the case of the European Union, compensation is being reduced; therefore, the opportunity of the strategy would be in sectors that have exceptions or countries with greater technological gaps. In the case of North America, as they are regulated markets at the regional level, it would be possible to work directly with companies by allowing compensation that includes forestry projects or with regional operators to market free assignments. In the case of Latin America, the evolution of the market should be expected, and the issue of prices for countries with taxes should be analysed. However, future monitoring is recommended for each of these countries in accordance with the commitments made at COP26.

For the carbon neutral and economic diversification strategy, at the time of having the projects, it is important to define the registration entity, as this is a fundamental factor to guarantee the ease of commercialisation and to obtain a better price per bond or reduction certificate, where registration entities such as the VCS and Gold stand out.

For this study, 239 companies from the energy chain, construction materials, steel, food and paper sectors were identified at an international level that may be interesting (either because they are consumers of coal or because they have commitments to reduce emissions or already participate in the voluntary market). In the carbon neutral and economic diversification strategy through the voluntary market and at the national level, 34 companies were identified. It is important to bear in mind that these companies would buy this type of reduction bond or certification to show their commitment to reducing greenhouse gases and social responsibility and to meet organisational objectives; they would not make changes to their processes and would be able to meet commitments.

This analysis makes it possible to demonstrate the potential that Colombia has to continue entering the voluntary market with innovative strategies and projects that are attractive from the supply and demand standpoints, from the volume of bonds to be generated and the cobenefits or additional impacts that they may generate. This could empower the productive sector, and in the case of the carbon-neutral strategy and economic diversification, it could be an opportunity to achieve its commercialisation in the medium term, seeking co-benefits and price improvements.

Based on these elements, carbon neutrality in Colombia has potential both in voluntary and regulated carbon markets. Initially, it could start in the voluntary market and hold specific negotiations with the countries that have a regulated market. In addition, including projects based on nature, especially reforestation and REDD, will be very beneficial since this sector is expected to experience the greatest growth in the creation of bonds. In addition, with the new rules of the COP26, there will be greater security, certainty, and integrity in accounting, which will be positive for

the carbon neutral and economic diversification strategy. How the agreements are implemented to identify opportunities and strategies in their implementation should be monitored. In addition, it is recommended that a staggered route plan be created that allows the establishment of the necessary activities and actions to develop the strategy and begin the processes of commercialising carbon neutrality. Countries and sectors should be prioritised according to their potential in the regulated or voluntary market.

All these findings are important as inputs for developing a carbon-neutral marketing strategy for Colombia based on the different opportunities offered by the market. New policies related to emissions reduction and trading should be followed up to define adjustments or greater possibilities for this type of initiative, especially based on the results of COP26, new and/or updated NDCs and Article 6 of the Paris Agreement with respect to the cooperative approach (Article 6.2) and compliance crediting mechanism (Article 6.4).

DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article and that the data that support the findings of this study are available from the corresponding author upon reasonable request.

AUTHOR CONTRIBUTIONS

Clara Inés Pardo Martínez: Conceived and designed the analysis, wrote the paper and performed the analysis. Alexander Cotte Poveda: Contributed to data or analysis tools, wrote the paper and performed the analysis.

CONFLICTS OF INTEREST

The authors declares that they have no conflicts of interest.

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