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RENEWABLE ENERGY AND CARBON MARKETS IN VIETNAM'S 2030 VISION TOWARDS 2050: A SYMBIOTIC PATH TO SUSTAINABLE DEVELOPMENT

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Abstract – *This research provides a comprehensive exploration of the symbiotic relationship between renewable energy initiatives and the evolving carbon markets in Vietnam's 2030 vision towards 2050, with a keen focus on the nation's journey toward sustainable development. By scrutinizing international and national policies, including the Kyoto Protocol and the Paris Agreement, the study delineates the institutional framework necessary for effective participation in the carbon market. Analyzing Vietnam's updated Nationally Determined Contribution (NDC), the research unveils sector-specific mitigation targets, emphasizing the country's potential to generate carbon credits. The article also sheds light on Vietnam's robust experience in carbon market preparedness, spanning Clean Development Mechanism (CDM) projects, Joint Crediting Mechanism (JCM) initiatives, and active engagement in the voluntary carbon market. Through these endeavors, Vietnam emerges as a key contributor to global efforts in fostering sustainable practices, technology transfer, and international collaboration, positioning itself prominently in the global transition toward a low-carbon economy.*

Keywords: carbon markets, Clean Development Mechanism, renewable energy, sustainable development, Vietnam.

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I. INTRODUCTION

In recent years, the convergence of renewable energy development and carbon market mechanisms has emerged as a strategic priority for nations pursuing sustainable, low-carbon growth. Vietnam, marked by rapid economic expansion and rising energy demand, stands at a critical crossroads in its transition toward a green and resilient future. This research undertakes a comprehensive analysis of Vietnam's renewable energy landscape and its evolving carbon market, with a focus on the factors shaping their development and interconnection. The urgency of this inquiry is underscored by the global momentum surrounding climate change mitigation, particularly in the wake of the Paris Agreement, which emphasizes the critical role of renewable energy and market-based instruments in reducing greenhouse gas (GHG) emissions [1]. According to the International Renewable Energy Agency (IRENA) [2], Vietnam's renewable energy capacity increased nearly twenty-fold between 2010 and 2019, signaling strong national momentum toward clean energy. This surge aligns with Vietnam's commitment to reducing GHG emissions and fostering a low-carbon economy. At present, Vietnam's economic growth continues to drive significant energy demand, much of which is still met by fossil fuels. Recognizing the associated environmental costs, the Vietnamese government has articulated ambitious plans for energy transition. The 2015 National Power Development Plan (PDP VII) sets a target for renewable energy to contribute 21% of total installed capacity by 2030 [3]. These commitments are further reinforced by the updated Nationally Determined Contributions

(NDCs), approved in 2020, which set out a domestic GHG reduction target of 9% below the Business-as-Usual (BAU) trajectory – scalable to 27% with international support [4]. Figure 1 illustrates the current status of Vietnam's carbon market development.

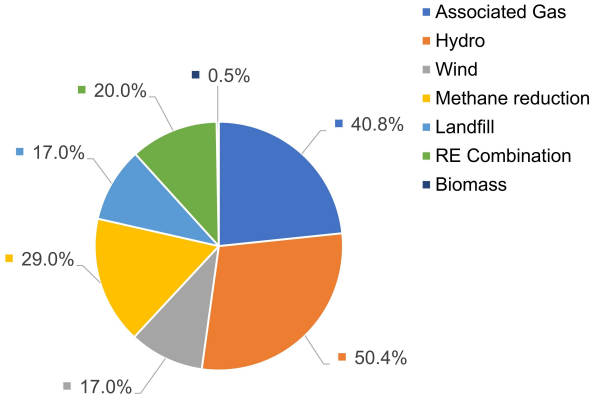

Fig. 1: Current status of Vietnam's carbon market [5]

Understanding the synergies between renewable energy development and carbon markets is essential to achieving Vietnam's climate objectives. Carbon markets provide an economic mechanism to incentivize emissions reductions, foster innovation, and monetize sustainable practices. Since their emergence under the Kyoto Protocol [6], carbon markets have evolved, with the Paris Agreement placing renewed emphasis on international cooperation through market-based approaches such as Article 6 [7]. Vietnam's exploration of carbon markets must be strategically aligned with its renewable energy transition. To inform alignment, this research offers a holistic assessment of the opportunities, constraints, and policy levers involved. It evaluates the interplay between domestic and international policy frameworks, mitigation potential, and Vietnam's practical experiences with market-based mechanisms, including historical participation in Clean Development Mechanism (CDM) projects, which deliver important lessons for the design of future initiatives.

Employing a multidimensional methodology that includes policy analysis, expert consultations, and multi-criteria analysis (MCA), the study provides a data-driven and contextualized evaluation of Vietnam's readiness for carbon market participation. By synthesizing insights from both the renewable energy and carbon market domains, this research fills a critical gap in the literature, moving beyond fragmented analyses to propose an integrated roadmap for Vietnam's low-carbon development. Its findings aim to support policymakers, businesses, and development partners in shaping coherent and forward-looking strategies for carbon pricing, renewable integration, and climate resilience.

II. LITERATURE REVIEW

Renewable energy and carbon markets have emerged as central pillars in the global response to climate change and the transition toward sustainable development. This literature review critically examines key scholarly and institutional contributions that explore the intersection of renewable energy development and carbon market participation. The review is structured across four thematic areas: the evolution of renewable energy, the dynamics of carbon markets, Vietnam's specific context, and the theoretical and methodological foundations that underpin this study.

A. Evolution of renewable energy

The global transition toward renewable energy has been extensively documented, reflecting an accelerating shift from conventional fossil fuels to cleaner, more sustainable energy systems. Key contributions from institutions such as the IRENA provide robust empirical data and trend analyses. IRENA's Renewable Capacity Statistics 2020 report reveals a nearly 20-fold increase in Vietnam's renewable energy capacity between 2010 and 2019, underscoring the country's accelerated efforts to diversify its energy mix [2]. While global assessments offer a macroscopic view, regionally focused studies provide critical insight into context-specific drivers and constraints. Sovacool et al. [8] emphasized that successful renewable energy adoption depends on an

integrated policy framework, technological readiness, institutional capacity, and societal acceptance. In Vietnam, such principles are embodied in national planning instruments such as the National Power Development Plans (PDPs) and the updated NDCs [5], which set ambitious targets for renewable energy deployment as a component of national climate mitigation strategies.

B. Dynamics of carbon markets

Carbon markets have undergone significant transformation since their inception under the Kyoto Protocol. Foundational works by Kollmuss et al. [9] provided a comprehensive critique of first-generation market mechanisms, highlighting both their potential and their limitations. The transition from compliance-based mechanisms, such as the CDM, to more decentralized and flexible approaches under the Paris Agreement, particularly Article 6, marks a pivotal evolution in global carbon governance [10]. Economic analyses by Aldy et al. [11] and Fischer [12] further elucidated the design and performance of cap-and-trade systems, emphasizing their cost-effectiveness in achieving emissions reductions. Recent studies have also explored the role of voluntary carbon markets, which offer additional avenues for climate finance and private sector engagement. Bakhsh et al. [13] examined the structure and growth of these emerging markets, which increasingly complement regulatory mechanisms and opportunities for carbon offsetting beyond national borders. Dawes et al. [14] analyzed the environmental integrity of voluntary offsets, raising concerns over additionality, permanence, and leakage risks. Together, these studies suggest that while voluntary carbon markets hold promise for scaling climate mitigation, they also require robust governance frameworks to ensure their credibility and alignment with global climate goals.

C. Renewable energy and carbon markets in Vietnam

Country-specific literature focused on Vietnam provides a nuanced understanding of the interplay between renewable energy deployment and carbon market readiness. Do et al. [15] investigated the evolving policy environment for renewable energy in Vietnam, identifying key drivers such as international development assistance, feed-in tariffs (FITs), and the integration of environmental sustainability into national energy strategies. Vietnam's participation in the CDM has been the subject of several evaluative studies. Nguyen et al. [16] assessed the implementation outcomes of CDM projects in the country, noting both their contribution to GHG mitigation and the challenges related to institutional capacity, monitoring, and long-term sustainability. These insights are essential for informing Vietnam's transition to new carbon market frameworks under the Paris Agreement, particularly in leveraging past experiences to shape future strategies.

D. Theoretical foundations and research methods

This study builds upon a robust theoretical foundation rooted in sustainable development theory, market-based environmental governance, and low-carbon transition frameworks. The symbiotic relationship between renewable energy expansion and carbon market participation is well-articulated in existing scholarship, reinforcing the relevance of an integrated analytical approach. Methodologically, the study draws on best practices in MCA and expert consultation, as demonstrated in the works of Klinsky et al. [17] and Aldy et al. [18]. These methods enable a structured evaluation of diverse and often competing factors influencing carbon market participation. By incorporating both qualitative insights and quantitative scoring, this approach ensures a balanced assessment of Vietnam's policy readiness, mitigation potential, and institutional experience. The use of MCA, in particular, provides a novel analytical lens through which to assess the interaction between enabling policies, technical potential, and Vietnam's evolving carbon market infrastructure. Additionally, the historical review of Vietnam's engagement with the CDM and the exploration of its emerging role in voluntary carbon markets enrich the understanding of its

trajectory and readiness to scale up participation in international climate mechanisms.

III. RESEARCH METHODS

This study adopts an integrated methodological approach that combines qualitative and quantitative techniques to evaluate the interconnection between renewable energy development and carbon markets in Vietnam.

1 – Desk study: The research begins with an in-depth desk study, reviewing international agreements, national strategies, regulatory frameworks, and relevant literature. This step establishes the policy and institutional context, identifying key instruments shaping Vietnam's renewable energy trajectory and carbon market development.

2 – Multi-criteria analysis: A central component of the methodology is MCA, employed to quantitatively assess Vietnam's readiness for carbon market participation. Key criteria, such as enabling policies, mitigation potential, and market experience, are scored on a 1–5 scale. Scores are informed by data analysis and expert judgment, providing a structured evaluation of Vietnam's capacity in both compliance and voluntary carbon market schemes.

3 – Expert consultation: To enrich analytical robustness, expert consultations were conducted with specialists in climate policy and market-based instruments. These discussions refined the selection and weighting of MCA criteria and validated findings. Expert input ensured relevance, mitigated bias, and anchored the study in practical experience.

4 – Data collection: Data were sourced from Vietnam's updated NDCs, policy reports, and supporting documentation on carbon markets and renewable energy. These data underpin the MCA and offer sectoral insights into Vietnam's mitigation commitments and market potential.

5 – Comparative analysis: The study integrates comparative analysis by examining international experiences with carbon markets, best practices, and their applicability to Vietnam's context. This benchmarking informs recommendations and highlights transferable models.

6 – Policy analysis: A systematic policy analysis was undertaken to examine Vietnam's legal frameworks, strategic plans, and institutional arrangements related to climate mitigation and market mechanisms. This helps identify both enabling conditions and regulatory barriers for effective carbon market participation.

By combining empirical data, structured evaluation, and expert insights, this mixed-methods approach ensures a comprehensive understanding of the synergies between renewable energy development and carbon market readiness in Vietnam. It provides a solid foundation for evidence-based recommendations and policy formulation.

IV. RESULTS AND DISCUSSION

A. Renewable energy initiatives in Vietnam

Vietnam's pursuit of sustainable development has accelerated a strategic transition toward renewable energy, driven by the dual imperatives of energy security and climate mitigation. Supported by abundant natural resources, including solar, wind, hydro, biomass, and emerging marine energy, Vietnam has demonstrated strong momentum in expanding its clean energy portfolio.

National trends and strategic orientation

Recent policy frameworks and national energy master plans have positioned renewable energy as a central pillar of Vietnam's long-term energy strategy. Governmental incentives, foreign direct investment, and international development cooperation have catalyzed growth across the sector. As illustrated in Figure 2, the past decade has seen rapid deployment in solar PV, wind, and hydropower, signaling both political will and market confidence.

Solar energy

Solar power has emerged as a cornerstone of Vietnam's renewable energy expansion, particularly in southern and central regions with high solar irradiance (5 kWh/m2/day) and 2,000–3,000 sunshine hours annually [15]. The theoretical solar potential exceeds 43.9 billion tons of oil equivalent, with a practical generation capacity estimated at 8 TWh/year [16, 17]. Policy incentives, such as FITs, tax exemptions, and

streamlined licensing, have spurred exponential growth in solar installations. By 2020, Vietnam had installed over 16 GW of solar capacity, placing it among Southeast Asia's leading solar markets [19].

Wind energy

Vietnam's coastal geography and elevated terrains provide ideal conditions for wind power. Wind resource mapping by Ministry of Industry and Trade (MOIT) and the World Bank identified wind speeds of 6.0–7.0 m/s in south-central and mountainous regions [19]. The country's technical wind potential is estimated at 26.8 GW [20]. Supportive policies, including competitive bidding and long-term power purchase agreements, have driven investment. As of 2020, Vietnam had over 600 MW of installed wind capacity, with numerous large-scale projects under development.

Hydropower

Hydropower remains a foundational element of Vietnam's energy mix. Leveraging its extensive river systems, the country has built substantial infrastructure, including both large-scale and small hydropower plants. By 2020, hydropower capacity exceeded 17 GW, reinforcing Vietnam's position as a regional leader in this domain [18].

Biomass energy

Vietnam's agricultural sector offers abundant biomass resources, such as rice husks, straw, bagasse, coffee husks, and wood chips, especially in the Mekong and Red River Deltas. Annual biomass availability includes 8 million tons of rice husks, 32 million tons of straw, and 6 million tons of bagasse [21, 22]. Biomass energy presents an opportunity for decentralized generation, emissions reduction, and waste valorization. Policy incentives, including preferential tariffs, have supported the deployment of biomass power plants. As of 2020, installed biomass capacity reached 500 MW [23, 24].

Geothermal energy

Preliminary assessments indicate that Vietnam holds 1,400 MW of geothermal potential, with over 300 hot springs ranging from 30^{o}C to 150^{o}C [25]. Enhanced geothermal systems (e.g., hot dry rock) are also viable, with favorable gradients at depths of 2 km. While still nascent, geothermal energy offers long-term prospects for baseload renewable generation.

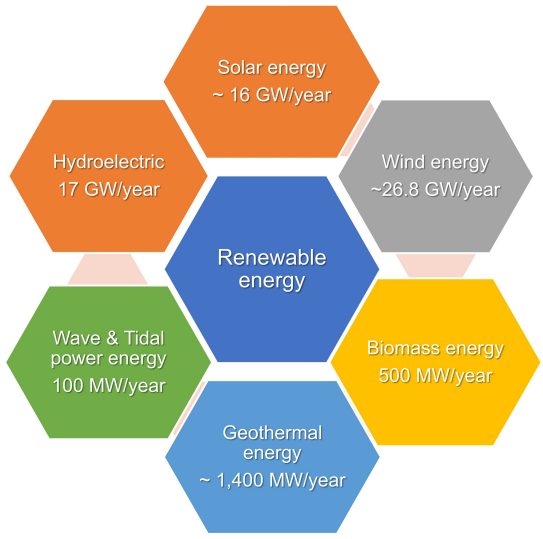

Fig. 2: Expansion of key renewable energy sources in Vietnam [15, 19–23]

Wave and tidal energy

Vietnam's extensive coastline and riverine deltas (e.g., Mekong and Red River) present promising sites for marine energy development. Theoretical wave and tidal potential is estimated at 100 MW/year [26, 27]. Although technological maturity and high capital costs remain challenges, ongoing research and international cooperation could pave the way for future deployment. Vietnam's renewable energy landscape reflects a dynamic and increasingly diversified portfolio, underpinned by a favorable policy environment, resource availability, and rising investment. With continued support and strategic planning, the nation is well-positioned to accelerate its clean energy transition, reduce reliance on fossil fuels, and contribute meaningfully to global climate targets.

B. Potential to generate carbon credits

Vietnam possesses significant potential to generate carbon credits across a wide spectrum of mitigation activities, reinforcing its strategic po-

sition in global carbon markets. This potential is a pivotal component of the nation's climate mitigation framework, as articulated in the updated NDC approved by the Prime Minister on 24 July 2020 [28]. The revised NDC outlines an ambitious GHG reduction target: a 9% cut relative to the BAU scenario by 2030 using domestic resources alone. With international financial and technical support, this target rises to 27%. These mitigation goals span five key sectors – energy, agriculture, industrial processes (IP), land use, land-use change and forestry (LULUCF), and waste – for the 2021–2030 period. As illustrated in Figure 3, the energy sector emerges as the dominant contributor, accounting for over 60% of the total mitigation potential. It is projected to reduce 51.5 $MtCO_2e$ through domestic efforts and up to 155.8 $MtCO_2e$ with external support. Cumulatively, all sectors are expected to yield a reduction of 83.9 $MtCO_2e$ by 2030 under unconditional scenarios and up to 250.8 $MtCO_2e$ under conditional commitments. These projections underscore the importance of robust measurement, reporting, and verification systems (MRV), effective policy implementation, and expanded access to international climate finance to fully realize Vietnam's carbon credit potential.

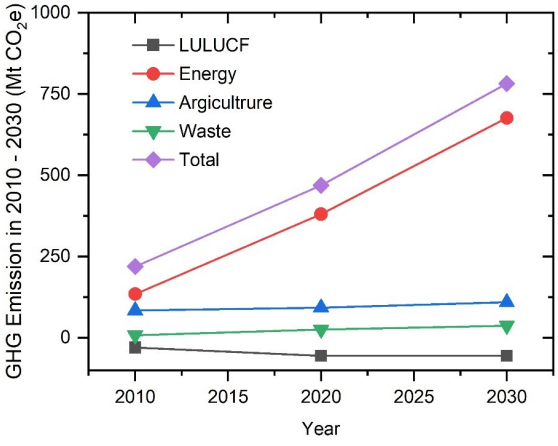

Fig. 3: GHG emissions in 2010 and projections for 2020 and 2030 ($MtCO_2e$) [3]

Vietnam's engagement in carbon markets is multifaceted, encompassing both compliance and voluntary mechanisms. The country has made significant headway through the CDM, with 257 registered projects – ranking fourth globally – and issuance of over 18 million Certified Emission Reductions (CERs). These initiatives have accelerated renewable energy adoption, enhanced energy efficiency, and improved waste management practices across key economic sectors [28]. Complementing this, Vietnam actively participates in the Joint Crediting Mechanism (JCM) – bilateral scheme with Japan – the deployment of advanced low-carbon technologies, and facilitating access to preferential carbon credits. These mechanisms not only bolster Vietnam's decarbonization agenda but also enhance its capacity for sustainable development through technology transfer and international cooperation. In parallel, Vietnam has expanded its footprint in the voluntary carbon market, with a growing number of projects registered under recognized standards such as the Verified Carbon Standard (VCS), and Gold Standard (GS). Currently, 17 projects are certified under VCS and 20 under GS, reflecting investor confidence and alignment with international best practices in carbon offsetting. Moreover, the Reducing Emissions from Deforestation and Forest Degradation (REDD+) initiatives focused on forest conservation and land-use change have contributed further to Vietnam's carbon credit portfolio, with co-benefits for biodiversity and community livelihoods. Figure 4 presents the projected installed capacity under Vietnam's low-carbon development pathway from 2030 to 2050. The scenario reveals a marked decline in fossil fuel dependency and a sharp increase in renewable energy deployment, particularly in solar, wind, and biomass. This structural shift in the national energy portfolio affirms Vietnam's readiness to anchor its carbon credit strategies in a fundamentally decarbonized energy system.

Collectively, Vietnam's robust participation in the CDM, JCM, and voluntary carbon markets, combined with its ambitious NDC commitments, underscores its emerging leadership in international carbon finance. The country's proactive pursuit of emission reduction strategies, sup-

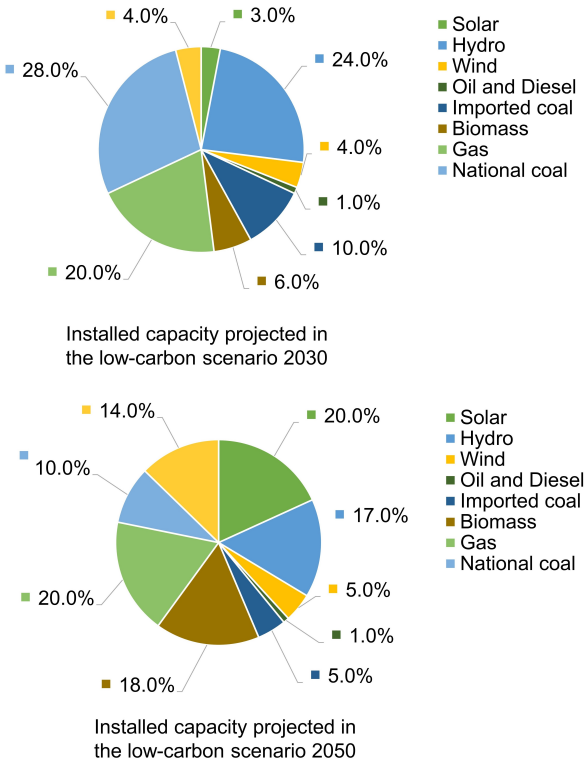

Fig. 4: Installed capacity projected in the low-carbon scenario (2030–2050) [29]

ported by a favorable policy environment and international cooperation, positions it as a key contributor to global climate mitigation efforts, while simultaneously unlocking pathways for sustainable economic transformation.

C. Readiness for the international carbon market

As Vietnam strategically positions itself within the evolving global carbon market, its preparedness is increasingly evident through policy advancements, institutional capacity-building, and proactive engagement in multilateral climate frameworks. The nation's readiness is underpinned by a comprehensive suite of initiatives aimed at enhancing its carbon market infrastructure and fostering a favorable environment for emissions trading and low-carbon development. Vietnam's active participation in international mechanisms such as the JCM, REDD+, and the voluntary carbon market provides a solid foundation for scaling up its engagement in compliance-based markets. These platforms have enabled Vietnam to pilot innovative climate solutions, attract climate finance, and strengthen technical capacity for emissions MRV – key prerequisites for credible participation in international carbon trading schemes.

A cornerstone of Vietnam's readiness lies in its alignment with global climate commitments. As a signatory to both the Kyoto Protocol and the Paris Agreement, Vietnam has consistently reaffirmed its intent to reduce greenhouse gas emissions in accordance with global climate goals. The country's updated NDC outlines quantifiable emission reduction targets and reflects a clear strategy for international cooperation and carbon market integration. At the national level, Vietnam has established a coherent institutional framework to support carbon market development. The Ministry of Natural Resources and Environment (MONRE), specifically through its Department of Climate Change, plays a central role in formulating policies, regulating carbon market activities, and overseeing MRV systems. To further streamline coordination, Vietnam established the Vietnam Carbon Market Development Coordination Board (VCB), tasked with guiding the design, implementation, and scaling of carbon trading mechanisms.

In tandem with institutional measures, Vietnam has made strides in the legal and regulatory domain. Recent policies have laid the groundwork for domestic carbon pricing instruments, including pilot emissions trading schemes (ETS), carbon credit certification standards, and market-based incentives to encourage private sector participation. These frameworks not only enhance transparency and market integrity but also align domestic efforts with Article 6 of the Paris Agreement, which governs international carbon markets and cooperative approaches. Vietnam's implementation of over 257 CDM projects and continued engagement in the JCM exemplifies its operational maturity in deploying mitigation activities with measurable climate benefits [30].

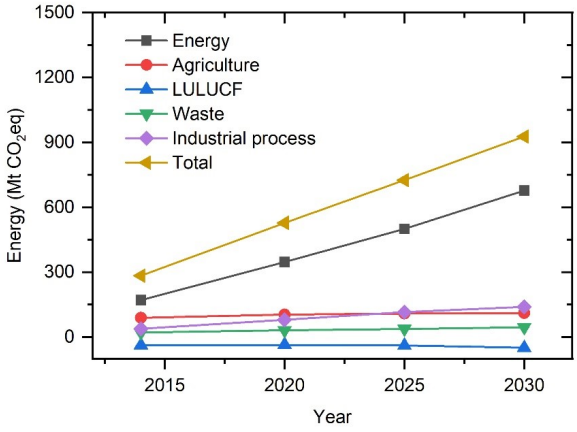

Fig. 5: GHG emissions under the BAU scenario [5]

These projects span renewable energy, energy efficiency, industrial process improvements, and waste management – sectors that are also prioritized in the national mitigation strategy. Additionally, Vietnam's participation in leading voluntary standards such as VCS and GS demonstrates a diversified market approach that engages both public and private actors in climate action. Looking ahead, Vietnam's capacity to generate and trade carbon credits is strongly aligned with its broader sustainable development and green growth objectives. The integration of low-carbon technologies, institutional reforms, and international cooperation mechanisms collectively positions Vietnam as a credible and capable actor in the global carbon market. As international demand for high-quality carbon credits rises, especially those with verifiable sustainable co-benefits, Vietnam is well-poised to meet this demand while advancing its climate resilience agenda.

In summary, Vietnam's readiness for the international carbon market is characterized by a robust policy environment, institutional architecture, project experience, and growing technical expertise. These attributes enable the country to capitalize on emerging carbon finance opportunities and reinforce its role as a proactive contributor to global climate mitigation efforts.

D. Integration of renewable energy and carbon market participation

Vietnam's transition to a low-carbon economy is closely tied to its renewable energy expansion and growing engagement in carbon market mechanisms. The synergy between these two domains not only supports the nation's climate commitments under the Paris Agreement but also unlocks economic opportunities through emissions reduction and carbon credit generation. As outlined in Vietnam's updated NDC, renewable energy deployment is a cornerstone of the national mitigation strategy, with sector-specific targets aligned to maximize carbon credit potential while accelerating green growth.

Renewable energy as a catalyst for carbon market entry

Renewable energy projects – particularly in solar, wind, and biomass – play a pivotal role in enabling Vietnam's participation in both compliance and voluntary carbon markets. By displacing fossil fuel-based energy generation, these projects contribute measurable emissions reductions, qualifying them for credit issuance under mechanisms such as the CDM and JCM. Empirical studies show Vietnam has considerable potential to scale carbon credit generation from renewables, with comparative assessments highlighting performance on par with regional peers like China and India, albeit with distinct regulatory and financial challenges. The establishment of institutions such as the Vietnam Renewable Energy Development Center (VRED) supports capacity-building, project development, and policy coordination, reinforcing the institutional framework necessary for carbon market engagement [31, 32]. Integration of renewable energy infrastructure with MRV systems ensures transparency and credibility in emissions accounting, which is critical for international trading eligibility.

Carbon market incentives driving renewable energy investment

Carbon markets play a critical role in accelerating renewable energy deployment by monetizing emission reductions through tradable credits, thus improving project bankability and attract-

ing investment. As demonstrated by Nguyen et al. [33] and Fischer et al. [12], carbon pricing instruments enhance the financial feasibility of clean energy projects, reduce investment risks, and strengthen investor confidence. Vietnam's active engagement in mechanisms such as the CDM and JCM illustrates its growing capability to leverage international carbon finance, aligning well with national renewable energy goals. This alignment fosters dual benefits: mobilizing foreign investment and technology transfer while building domestic capacity for large-scale mitigation. Comparative studies from China and India confirm the reinforcing relationship between carbon market participation and renewable energy growth [19–27]. In Vietnam, renewable energy projects generate tradable carbon credits under CDM and JCM, boosting financial viability and integration into global carbon markets. Strategically embedding carbon market incentives into Vietnam's renewable energy policy accelerates the clean energy transition, supports its NDC commitments, and positions the country as a key player in international carbon trading and sustainable development.

Policy framework for synergistic integration

A coherent policy framework is essential for integrating renewable energy development with carbon market participation in Vietnam. Key legislative instruments, including Resolution No. 24-NQ/TW [34], the Law on Environmental Protection (No. 55/2014/QH13) [35], Decision No. 2068/QD-TTg implementing the Paris Agreement [36], and Decision No. 2359/QD-TTg establishing a national GHG inventory [37] – demonstrate Vietnam's strategic prioritization of climate action. These are supported by policy tools such as FITs, renewable portfolio standards, and draft ETS regulations, all aimed at incentivizing investment in low-carbon technologies and ensuring alignment with Article 6 of the Paris Agreement. Additionally, the legal framework for the Clean Development Mechanism (e.g., Directive No. 35/2005/CT-TTg [38] and Circular No. 15/2014/TT-BTNMT) [39] enables renewable energy projects to access international carbon finance. While a fully integrated MRV system is still under development, the existing national GHG inventory forms a foundational element for emissions monitoring, reporting, and verification, facilitating Vietnam's transition toward a low-carbon economy. In support of this policy infrastructure, Table 1 presents the MCA scores for Vietnam's carbon market readiness, offering an empirical foundation for assessing the country's institutional, technical, and policy preparedness to engage effectively in global carbon trading mechanisms.

Table 1: Multi-criteria analysis (MCA) scores for Vietnam's carbon market readiness

Factors	MCA score	Expert opinion
Supporting policies	8.5	High
National mitigation targets	7.9	Moderate
Current experience & potential	5.2	Low

E. Strategic vision and institutional support

Vietnam's strategic roadmap, outlined in Decision No. 2053/QD-TTg [40], Resolution No. 93/NQ-CP [41], and the National Strategy on Green Growth [42], underscores a long-term vision for decarbonization, sustainable development, and carbon market integration. These high-level strategies embed emissions mitigation in broader economic planning, establishing carbon trading as a key pillar of the country's climate finance ecosystem. Institutional mechanisms, such as the Vietnam Carbon Market Development Coordination Board and sector-specific MRV systems, are being developed to enhance regulatory oversight and facilitate international linkage. Vietnam's regulatory advancements, coupled with institutional momentum, create a robust foundation for synergizing renewable energy deployment with carbon market participation.

F. Vietnam's experience in carbon markets: CDM and voluntary mechanisms

Vietnam has emerged as a notable actor in global carbon markets, particularly through its participation in the CDM and various voluntary

carbon market initiatives. This section highlights Vietnam's achievements, persistent challenges, and its evolving trajectory in the international carbon trading landscape.

Achievements and challenges in the CDM

By June 2020, Vietnam had registered 257 CDM projects and 13 Programs of Activities, ranking fourth globally in project volume. The energy sector dominates (87.6%), followed by waste management (10.2%) and afforestation (0.4%), collectively contributing over 140 million tCO_2e in potential emissions reductions. Vietnam ranks sixth globally in CERs, with over 18 million CERs issued, underscoring its early and effective engagement with CDM frameworks [30]. These projects have catalyzed technology transfer, capacity building, and international recognition. However, key barriers remain. Vietnam's MRV infrastructure lacks consistency and integration, and national guidelines for CDM implementation require further clarification. Enhancing institutional coordination and regulatory transparency will be critical for future carbon market mechanisms.

Voluntary market engagement and bilateral cooperation

Vietnam's engagement in voluntary carbon markets reflects a diversified and proactive strategy to advance climate mitigation through international cooperation and private sector participation. Through the JCM, established with Japan in 2013, Vietnam has facilitated bilateral emission reductions by enabling access to advanced low-carbon technologies and co-financing, with up to 50% of project costs supported. Additionally, Vietnam hosts 17 projects under the VCS, with 603,417 credits issued, and 20 projects under the GS, generating 3.27 million credits, demonstrating growing investor confidence and domestic project development capacity [43]. Participation in the UN-REDD+ Program further highlights Vietnam's commitment to reducing emissions from deforestation and forest degradation, aligning its efforts with global nature-based solutions. While challenges remain, particularly in MRV systems, regulatory clarity, and market liquidity, these initiatives collectively position Vietnam as an emerging leader in the voluntary carbon market space.

Comparative and policy analysis

Comparative insights from the EU Emissions Trading System (EU ETS) and Japan's JCM reveal critical lessons for Vietnam. While these models benefit from advanced regulatory infrastructure and market integration, Vietnam must tailor its strategy to domestic socio-economic contexts. Vietnam's alignment with international frameworks – UNFCCC, Kyoto Protocol, and Paris Agreement – has fostered enabling conditions for carbon market development. National policies, such as Circular No. 15/2014/TT-BTNMT and Decision No. 1775/QĐ-TTg [44, 45], offer legal scaffolding for carbon credit issuance and project finance. However, further harmonization across ministries and clearer guidelines remain necessary to unlock full market potential.

G. Drivers and determinants of carbon market development in Vietnam

Vietnam's carbon market development is driven by a dynamic interplay of economic growth, regulatory frameworks, technological advancement, and socio-political engagement. Rapid industrialization has led to escalating GHG emissions, prompting the adoption of carbon pricing instruments to catalyze low-carbon transitions [16]. Policy initiatives such as the National Green Growth Strategy and regulatory directives like Decision No. 2359/QĐ-TTg [37] provide a foundational governance structure for carbon market integration, emphasizing the establishment of robust MRV systems and market-based mitigation approaches. Technological innovation, including renewable energy deployment, digital MRV platforms, and blockchain-enabled tracking, enhances transparency, efficiency, and the scalability of carbon credit trading [46]. Meanwhile, social factors like public awareness, stakeholder engagement, and international cooperation, particularly through mechanisms like CDM and JCM, reinforce Vietnam's technical

preparedness and global alignment. This study applies a multi-dimensional methodology incorporating MCA, expert consultation, and comparative benchmarking to holistically assess Vietnam's institutional, technical, and market readiness, distinguishing between conditional and unconditional NDC contributions and offering fresh insights into JCM implementation. Synthesizing these findings, the research provides strategic guidance for institutional reform, investment mobilization, and global collaboration, highlighting Vietnam's readiness to capitalize on carbon markets. By aligning renewable energy initiatives with carbon market mechanisms within a cohesive legal and strategic framework, Vietnam is well-positioned to unlock significant climate, economic, and technological value, emerging as a regional leader in the global transition to a low-carbon economy.

V. CONCLUSION AND RECOMMENDATIONS

This study underscores the critical synergy between renewable energy deployment and carbon market participation in advancing Vietnam's low-carbon development pathway toward 2030 and 2050. By analyzing international frameworks such as the Kyoto Protocol and the Paris Agreement alongside Vietnam's updated NDC, the research highlights the country's institutional readiness and significant potential for carbon credit generation. Vietnam's achievements in mechanisms like the CDM, JCM, VCS, and GS reflect its growing role in global climate mitigation and technology transfer. To maximize impact, the study recommends enhancing MRV systems, streamlining institutional coordination, building technical capacity, strengthening international cooperation under Article 6 of the Paris Agreement, and aligning carbon market incentives with renewable energy goals. Collectively, these actions will position Vietnam as a regional leader in climate governance and support a sustainable, resilient, and prosperous future.

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