Financial Support for the Development of Green Energy Industry under the WWS Energy System Transition

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Abstract. The transition to a Wind-Water-Solar (WWS) energy system is essential for global decarbonization, demanding significant financial support, particularly in complex multi-jurisdictional regions like the Guangdong-Hong Kong-Macao Greater Bay Area (GBA). Characterized by its unique 'one country, two systems' framework, the GBA offers a critical case study of the multi-level governance (MLG) challenges involved in financing a large-scale WWS transition. Applying a Multi-level Governance (MLG) framework, this research analyzes the financial and regulatory barriers impeding WWS development in the GBA, arguing that key issues—such as fragmented policies, capacity disparities, data asymmetry, and weak accountability—stem from governance failures. These shortcomings collectively increase transaction costs, encourage regulatory arbitrage, and undermine efficient capital allocation, ultimately slowing the WWS transition. To address these challenges, this research proposes a tripartite policy framework: establishing a Green Finance Coordination Council to align standards, designing a blended finance mechanism to mitigate risks, and implementing a mandatory ESG disclosure framework to enhance transparency. By both identifying GBA-specific governance failures and offering targeted solutions, this paper presents a replicable MLG-based framework for guiding sustainable energy transitions in other complex, multi-jurisdictional regions globally.

Keywords: Green Energy Finance; WWS Transition; Multi-Level Governance; Greater Bay Area.

1. Introduction

The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) underscores a critical threshold: global average temperature has already risen by approximately 1.1°C above pre-industrial levels. Without the implementation of aggressive emission reduction measures, the temperature increase during the 21st century may far exceed the 1.5°C target set in the Paris Agreement. The urgency of climate change has catalyzed a global transition towards renewable energy. The Wind-Water-Solar transition, which exclusively utilizes wind, hydro, and solar power to replace world energy, presents a sustainable pathway to decarbonize the economy [1]. The development of the green energy industry, however, is capital-intensive, characterized by high upfront costs, long payback periods, and significant technological risks. This inherently necessitates robust financial support mechanisms to facilitate its growth and integration into the mainstream energy mix [2]. Developing the green energy industry is not only an imperative for addressing climate change but also a significant economic opportunity. It holds the potential to promote the transformation and upgrading of traditional industries, generate new employment opportunities, reduce total final energy consumption, and enhance energy security levels.

Addressing this financing challenge has become a central focus of scholarly inquiry. The academic discourse has extensively explored the critical intersection of green finance and renewable energy development, providing a foundational understanding of the mechanisms that can facilitate the transition to a WWS-based system. A significant body of research emphasizes the pivotal role of public policy and directed credit in de-risking investments and improving the bankability of renewable projects. Polzin et al. found FITs cut project risk, auctions/RPSs suit mature tech, and policy credibility attracts investment, which is critical for high-risk WWS projects [2]. Bhutta et al. concluded that favorable regulation, better disclosure, and third-party verification promote green bonds, which may lower financing costs [3]. Furthermore, research has expanded to include innovative financial instruments. Tolliver, Keeley, & Managi analyzed the burgeoning green bond

market, proposing that its standardized frameworks and dedicated investor base offer a viable channel for raising large-scale, long-term capital essential for major wind and solar infrastructure projects [4]. However, while the existing literature proficiently analyzes individual financial instruments or macro-level policies, a more integrative and contextualized approach is needed. Berensmann & Lindenberg note that many studies operate in silos, examining either credit, bonds, or carbon markets in isolation, rather than as a synergistic ecosystem [5]. This gap becomes particularly evident when examining unique economic regions with complex governance structures, such as China's Greater Bay Area (GBA). Within such strategic contexts, there remains a notable shortage of comprehensive studies that integrate and holistically examine multi-dimensional financial support mechanisms—including policy banks, green bonds, carbon finance, and equity markets—specifically designed to facilitate the transition to wind-water-solar (WWS) energy systems. Existing literature tends to be either highly theoretical or narrowly focused, often lacking the empirical depth needed to translate financial concepts into actionable, region-specific policy frameworks.

This paper proposes targeted policy suggestions to optimize the financial ecosystem to support the WWS transition in the GBA. To provide a robust analytical structure for this complex, multi-jurisdictional case, this paper adopts the Multi-level Governance (MLG) Framework to elucidate the governance challenges and propose coordinated solutions.

The complex, multi-jurisdictional nature of the GBA demands an analytical framework capable of dissecting its unique governance challenges. This paper employs the Multi-level Governance (MLG) framework for this purpose. The Multi-level Governance (MLG) framework, originating from the study of European integration, provides a powerful lens for analyzing policymaking in systems where authority is dispersed across multiple, overlapping jurisdictions. It moves beyond traditional, state-centric models to acknowledge the roles of sub-national (e.g., regional, municipal) and supra-national actors, as well as non-state entities (e.g., private sector, NGOs), in the governance process. MLG is characterized by two key dimensions: 1) the dispersion of authority across multiple territorial levels (vertical dimension), and 2) the collaboration between public and private actors within these levels (horizontal dimension). This framework is particularly adept at diagnosing problems of policy fragmentation, coordination failure, and jurisdictional overlap, precisely the challenges inherent in governing a cross-border issue like green finance within the complex "one country, two systems" architecture of the GBA. This paper employs the MLG framework to analyze how the current fragmented governance structure impedes financial flows for WWS projects and to propose mechanisms for enhanced coordination.

2. Case Description: The GBA's Multi-level Green Ambition

The Guangdong-Hong Kong-Macao Greater Bay Area (GBA) represents a compelling case study of multi-level governance challenges and opportunities. Its development is driven by a national-level strategic directive from Beijing, outlined in the Outline Development Plan, which prioritizes green growth [6]. At the sub-national level, the eleven cities possess varying degrees of autonomy and capacity to execute this vision. Guangdong province and its nine cities are spearheading the deployment of physical WWS projects, such as offshore wind farms in Jiangmen and Yangjiang. By contrast, the special administrative regions of Hong Kong and Macau, operating under distinct legal and financial systems, are pursuing their own green agendas; Hong Kong, as a global financial node, is focusing on becoming a regional green finance hub, developing its own green bond standards and market practices. This multi-level structure, while rich in resources, creates a complex governance landscape where policies, standards, and priorities must be aligned across different political and administrative systems. This structural complexity, while fostering innovation through diversity, necessitates sophisticated coordination mechanisms to align carbon accounting methodologies, green certification standards, and cross-border capital flows - precisely the challenges our MLG framework is designed to address.

3. Analysis of the Problem: A Multi-level Governance Dilemma

3.1. Structural Advantages: The Theoretical Potential of the GBA's MLG Framework

3.1.1 Strategic guidance and macro-policy support from the national level

The central government provides indispensable top-level design and strategic direction for the GBA's green transition. Through the promulgation of the Outline Development Plan for the Guangdong-Hong Kong-Macao Greater Bay Area, it explicitly incorporates green and low-carbon development as a core regional objective, thereby establishing a clear political signal and policy expectation [6]. Furthermore, the national level leverages its fiscal and regulatory authority to allocate special funds and introduce tax incentives specifically targeted at renewable energy projects and green technology innovation. This high-level commitment not only legitimizes the green agenda but also creates a stable, long-term framework that helps mitigate policy uncertainty for investors and stakeholders.

3.1.2 Efficient project implementation and industrial scaling at the sub-national level

Provincial and municipal governments demonstrate strong execution capabilities in materializing the national strategic vision. They translate macro-policies into concrete projects, such as the large-scale offshore wind farms in Jiangmen and Yangjiang and the widespread deployment of distributed solar PV systems across industrial parks in Shenzhen and Dongguan. This level of government excels in land acquisition, local coordination, and providing complementary supporting infrastructure, which are critical for the rapid scaling and physical deployment of WWS technologies. Their proximity to the projects allows for more responsive and context-specific governance, addressing local barriers and facilitating cluster development that leverages regional industrial strengths.

3.1.3 Specialized financial intermediation and international market access via Hong Kong SAR

Hong Kong's unique role as a global financial center within the MLG framework provides a critical gateway to international capital and expertise. It facilitates the mobilization of global green capital through sophisticated financial instruments, most notably the issuance of green bonds aligned with international standards. The city's robust legal framework, adherence to international norms, and deep pools of professional service providers enhance the credibility and bankability of GBA green projects for international investors. This function is pivotal in bridging the domestic WWS project pipeline with global liquidity, thereby alleviating funding constraints and reducing the cost of capital through enhanced competition and risk diversification [4].

3.2. Problem Analysis: Governance Fragmentation and Coordination Failure

The core challenge in any Multi-level Governance system, as identified by Hooghe & Marks, is navigating the tension between autonomy and coordination.

Despite these theoretical advantages, the current multi-level governance system in the GBA demonstrates significant fragmentation in practice, leading to systemic coordination failures. According to the classic discussion by Hooghe & Marks, the core challenge facing MLG systems lies in establishing effective coordination mechanisms among different government levels, an area where the GBA is experiencing severe tests [7].

3.2.1 Vertical and horizontal misalignment

From an MLG perspective, policy fragmentation essentially represents an external manifestation of governance structural deficiencies. Vertically, while the national outline sets common goals, there is a lack of effective vertical coordination mechanisms to ensure uniform implementation of these goals across different legal systems. There are differences in goals between local governments and the central government, which lead to deviations in policy implementation. Horizontally, there is evident competition rather than collaboration among cities. Hong Kong adopts Environmental, Social, and Governance standards based on international capital markets, while mainland cities primarily

follow the Green Industry Guidance Catalogue issued by the National Development and Reform Commission. This creates a fundamental institutional schism within the GBA's governance framework. This institutional difference creates regulatory arbitrage opportunities and increases the complexity of policy compliance. According to North's institutional theory, this incompatibility within the institutional matrix significantly increases transaction costs and hinders the free flow of factors [8]. Enterprises are forced to undergo dual certification to meet requirements across jurisdictions, with estimated compliance costs accounting for 3-5% of total project investment, severely eroding the economic viability of WWS projects.

3.2.2 Sub-national capacity gap and risk aversion

MLG theory emphasizes that capacity heterogeneity among actors at different levels may lead to imbalances in system performance [9]. Significant disparities exist among GBA cities in terms of financial regulatory capacity, expertise in green technology assessment, and risk management capabilities. Hong Kong possesses Asia's most sophisticated financial regulatory system and professional talent pool, enabling the design of complex green financial derivatives. In contrast, local financial institutions in the nine mainland cities of the GBA generally lack the professional capacity to assess the technical risks and long-term environmental benefits of WWS projects. This capacity asymmetry leads financial institutions to adopt the most conservative risk management strategies, either rejecting financing or requiring excessive collateral guarantees. World Bank research indicates that in green projects in developing countries, financing cost premiums resulting from inadequate risk pricing capabilities of local financial institutions can reach 200-300 basis points. This phenomenon is equally evident in the GBA, where the capacity gap described above likely contributes to a similar, if not greater, risk premium for innovative WWS projects, as many innovative WWS projects face financing difficulties due to the inability to meet traditional banks' collateral requirements.

3.2.3 Reinforced data asymmetry in a multi-level system

Information economics theory suggests that market failures often stem from information asymmetry [10]. In the GBA's multi-level governance structure, this problem is further amplified. Governments at various levels, regulatory agencies, and market participants maintain independent data systems, lacking unified data governance frameworks and sharing protocols. The Hong Kong Monetary Authority requires stringent stress testing and climate risk disclosure based on BCBS standards, while mainland regulators focus more on traditional financial indicator supervision. This inconsistency in regulatory data requirements creates a dual reporting burden for enterprises while making it difficult for investors to obtain comparable information for investment decisions. According to International Energy Agency research, the lack of standardized, verifiable environmental benefit data is one of the main obstacles hindering green investment. In the GBA, this problem is exacerbated by the multi-level governance structure—no authoritative institution can mandate cross-jurisdictional data standardization, and cities often hesitate to share key industrial data due to competitive concerns, resulting in a regional "data silo" dilemma. This directly undermines the GBA's strategic goal of deep regional integration and creates a fundamental barrier to allocating capital efficiently across the region based on a unified understanding of risk and return.

3.2.4 Blurred accountability and weak enforcement

An inherent challenge of multi-level governance systems is the decentralization of accountability mechanisms. This issue is particularly prominent in the WWS development of the GBA. When green transition goals are not achieved, accountability becomes diffuse and difficult to assign. This accountability ambiguity leads to a lack of rigid constraints in policy implementation. For example, the chapter on green financial cooperation proposed in the Outline Development Plan for the Guangdong-Hong Kong-Macao Greater Bay Area has progressed slowly in practice due to the absence of clear timelines, roadmaps, and accountability mechanisms. Meanwhile, varying enforcement standards across jurisdictions further distort the market competition environment: Hong Kong maintains a strong legal environment and regulatory enforcement capacity, while mainland

cities often exhibit varying stringency in environmental law enforcement. This differential further undermines policy consistency and effectiveness.

4. Suggestions

Building upon the Multi-level Governance analysis of the barriers impeding green finance for WWS projects in the GBA, this section proposes a set of integrated, multi-tiered policy recommendations. These suggestions are designed explicitly to enhance vertical coordination and horizontal collaboration, thereby creating a more coherent and effective financial ecosystem for the energy transition. These recommendations directly address the four core challenges identified in Section 3: (1) policy fragmentation, (2) capacity asymmetry, (3) information gaps, and (4) accountability diffusion.

4.1. Creating an Institutional Anchor: The GBA Green Finance Coordination Council

To directly address the critical issue of policy and regulatory fragmentation, the establishment of a formal, high-level GBA Green Finance Coordination Council is paramount. This council should function as a permanent governance platform, comprising senior financial regulators, policymakers, and technical experts from key national ministries, the Hong Kong Monetary Authority, the Macao Monetary Authority, and the leading development and reform commissions of Guangdong province and its nine cities. Its primary mandate would not be to dictate policy but to harmonize and align it. The council's most crucial output should be the development and maintenance of a GBA Common Green Taxonomy, which integrates the strengths of international standards with China's national green bond endowment catalogue. This unified framework would eliminate the current jurisdictional arbitrage and significantly reduce due diligence costs for cross-border investors. Furthermore, the council should facilitate the mutual recognition of green financial products certified under this common standard across the entire GBA, thereby creating a larger, more liquid pool of assets and enabling seamless capital flow [4,5]. The council's decisions should be binding and supported by a joint oversight mechanism involving the National Development and Reform Commission and the People's Bank of China.

4.2. De-risking Investment through a Multi-layered Capital Stack and Blended Finance Facility

To overcome the pervasive risk-return mismatch and attract private capital, particularly for early-stage and innovative WWS technologies, a sophisticated blended finance mechanism is essential. The proposals for the creation of a GBA Green Transition Fund, strategically capitalized with public and "patient" capital from multiple governance levels. This includes anchor investment from national-level green funds (e.g., National Green Development Fund), fiscal contributions from the Hong Kong SAR and Guangdong provincial governments, and capital from multilateral development banks like the Asian Infrastructure Investment Bank. The fund's design must incorporate a multi-layered capital stack where public capital absorbs the first-loss risk, so that senior tranches can attract commercial investors like pension funds and insurance companies seeking lower-risk, stable returns. This fund should specifically target projects that struggle to secure commercial financing, such as those led by Small and Medium-sized Enterprises(SME), projects involving pre-commercial technologies (e.g., green hydrogen, advanced energy storage), and infrastructure in less developed municipalities. By strategically using public capital to crowd in private investment, this facility would directly mitigate the sub-national capacity gap and risk aversion identified in the analysis [2].

4.3. Instituting a Mandatory and Collaborative GBA ESG Data Disclosure Framework

A robust data governance mechanism across the region is essential to tackle information asymmetry. The proposed Coordination Council should mandate a unified GBA ESG Data Disclosure Framework, rather than relying on voluntary participation. This framework must specify a

standardized suite of metrics consistent with the International Sustainability Standards Board (ISSB), yet also integrate indicators unique to the GBA. These would cover environmental performance, financial outcomes, and risk exposure. All green financing applications beyond a defined scale threshold would be subject to these requirements. Implementation would occur in three stages: initial trials with publicly traded companies (2024–2025), subsequent extension to firms exceeding RMB 100 million in annual revenue (2026–2027), and eventual inclusion of small and medium-sized enterprises (2028 onward). A digital platform—the GBA Green Data Hub—should be established to centralize the collection, authentication, and distribution of standardized disclosures. A cross-jurisdictional supervisory committee with broad regional representation ought to manage this platform. Tying disclosure compliance to qualification for preferential financing through the GBA Green Transition Fund and other public incentives would strengthen enforcement and enhance market trust. Transparent data access will help investors improve risk evaluation, support the creation of innovative financial instruments such as green ABS, and cut capital costs by mitigating uncertainty premiums [11].

5. Conclusion

This study has employed a Multi-level Governance (MLG) framework to analyze the complexities of financing the Wind-Water-Solar (WWS) energy transition within the Guangdong-Hong Kong-Macao Greater Bay Area (GBA). The analysis confirms that the region's unique polycentric governance structure, while rich in resources and potential, is currently characterized by significant coordination deficits and institutional misalignment that hinder the efficient mobilization of capital for green energy projects. This study, therefore, moves beyond a mere identification of financing barriers. It elucidates how the very structure of multi-level governance—while a source of potential strength—can become a primary impediment to capital mobilization if coordination mechanisms are not deliberately designed and implemented. Core issues include policy fragmentation across jurisdictions, capacity asymmetry among local financial institutions, severe information gaps due to inconsistent data standards, and blurred accountability mechanisms. To systematically address these interconnected challenges, our proposed policy framework is explicitly designed to target each failure point of the current MLG system: these governance failures increase transaction costs, create regulatory arbitrage, and hinder efficient capital allocation. To address these, the paper proposes an integrated policy framework: establishing a GBA Green Finance Coordination Council to harmonize standards, creating a blended finance facility to de-risk investments, and implementing a mandatory ESG data disclosure framework to enhance transparency and reduce information asymmetry.

This research provides practical insights for policymakers, financial regulators, and industry stakeholders involved in regional green energy transitions. The actionable recommendations offered—centered on institutional anchoring, blended finance, and data governance—are tailored to the GBA's unique 'one country, two systems' context. However, the underlying principle of designing coordinated mechanisms to overcome polycentric governance dilemmas offers a replicable model for other mega-regions and federal systems pursuing integrated low-carbon development. Success in this endeavor would not only advance regional carbon neutrality goals but also solidify Hong Kong's position as a leading global green finance hub. The study contributes to the broader discourse on green finance governance and offers a replicable model for other mega-regions pursuing integrated low-carbon development. It supports the GBA's ambition to become a global leader in green finance and sustainable energy.

Notwithstanding these contributions, this study acknowledges certain limitations. Primarily, its reliance on secondary data and policy documents, while providing a broad structural perspective, limits the granular understanding of micro-level decision-making processes and on-the-ground implementation challenges faced by individual enterprises and local financial institutions.

While this macro-level analysis provides a necessary diagnostic of systemic barriers, it inevitably leaves micro-level behavioral questions unanswered. To bridge this gap and translate high-level

policy into ground-level action, future research should focus more on field investigations and primary data collection. Subsequent studies should therefore employ mixed-methods approaches. Qualitative fieldwork, including semi-structured interviews with policymakers, financial officers, and project developers, is essential to uncover the operational logics and interest coordination processes within the MLG system. Quantitatively, constructing a granular project-level dataset would allow for rigorous econometric analysis to precisely measure the impact of specific policy tools on financing costs and investment decisions. Combined with quantitative analysis, such research could further clarify the impact mechanisms of various policy tools on financing conditions, thereby providing more granular support for building a more efficient and inclusive green financial ecosystem.

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