Supplementary Materials

Green Bonds and Sustainable Finance: Credibility Architectures, Challenges and Implications for the Green Transition

This file contains supporting material moved from the main manuscript to improve conciseness while preserving transparency and traceability.

Table S1. Geographic positioning of the green-bond credibility debate.

Geographic focus	Dominant research emphasis	Relevance for this paper
China and Hong Kong	State support, corporate behaviour, greenwashing, environmental performance, innovation and regulatory arbitrage	Shows why China is central to debates on state-linked eligibility, supervision, greenwashing and real environmental outcomes
Europe and EU	Transparency, greenium, taxonomy alignment, EU Green Bond Standard and formal regulation	Supports the distinction between voluntary market credibility and legally structured credibility
Global/cross-country samples	Greenium, liquidity, certification, external review and investor demand	Shows that market outcomes are widely studied, but often without unpacking the institutional architecture behind the label
Asia/ASEAN	Regional market development, policy support, sovereign issuance and regional standards	Provides context for regional-label credibility and Asian sustainable bond-market development
India and other emerging markets	Market barriers, policy incentives, transaction costs, lack of awareness and institutional constraints	Supports the argument that credibility architectures depend on institutional maturity and market development
United States and other advanced markets	Municipal green bonds, investor response, climate-risk pricing and market-based demand	Provides a useful comparison with advanced-market green-bond settings, but is less central to the frameworks analysed in this article

Note. The table summarises the main research emphasis associated with each geographic area on the basis of the scoping reading. It is intended as an interpretive framing device, not as a systematic country-level bibliometric ranking.

Table S2. Practical criteria for assessing environmental additionality claims.

Criterion	Credibility question	Implication for additionality claims
Financing/refinancing share	What proportion of proceeds finances new activity, and what proportion refinances existing assets, expenditures or debt?	A higher refinancing share weakens the inference that the bond created incremental environmental activity unless safeguards are explicit.
Look-back period	How far back may refinanced assets or expenditures be counted as eligible?	Longer look-back periods generally reduce the strength of additionality claims because the activity may have been completed or committed before issuance.
Asset age and remaining useful life	How old are the refinanced assets and how much useful life remains?	Age and remaining useful life help distinguish maintenance of green assets from new environmental activity.
Project status before issuance	Was the project already approved, budgeted, under construction or operating before the bond was issued?	Projects already committed before issuance require more cautious communication of incremental contribution.
Counterfactual baseline	What would likely have happened without the green bond?	A stronger claim requires evidence that the bond accelerated, expanded, enabled or materially changed the environmental activity.
Double-financing safeguards	Are there rules preventing the same asset or expenditure from being counted under multiple green instruments?	Double-financing exclusions protect the integrity of impact and allocation claims.
Impact measurement quality	Are baselines, system boundaries, greenhouse-gas accounting and life-cycle assumptions transparent and comparable?	Better measurement architecture strengthens impact credibility but does not by itself prove counterfactual additionality.
Claim differentiation	Does the framework distinguish eligibility, allocation, verification and additionality?	Clear differentiation prevents procedurally credible bonds from being marketed as environmentally additional when that stronger claim is not supported.

Note. These criteria do not imply that every green bond must demonstrate strict counterfactual additionality. They help distinguish weaker procedural claims from stronger environmental-contribution claims.

Table S3. Evidence anchors for verified coding matrix.

The evidence anchors below summarise the primary-document basis for the High/Medium/Low codes reported in the main manuscript.

Framework	Credibility mechanism	Code	Evidence anchor and source
EU European Green Bond Standard	External review / verification	High	The EuGB label requires pre-issuance review of the European Green Bond factsheet and post-issuance review of the allocation report after full allocation. External reviewers are also subject to registration and supervision. Source: Regulation (EU) 2023/2631, Arts. 10(1)(b), 11(4), 22.
EU European Green Bond Standard	Supervision / sanctions	High	External reviewers must be registered with ESMA; ESMA has supervisory powers over reviewers; competent authorities may impose administrative penalties for issuer infringements; financial penalties are specified for external reviewers. Source: Regulation (EU) 2023/2631, Arts. 22, 44, 49, 60.
EU European Green Bond Standard	Refinancing governance	High	Eligible-use rules include timing constraints for certain uses of proceeds, and the allocation-reporting template requires disclosure of the share of proceeds used for financing and refinancing. Source: Regulation (EU) 2023/2631, Art. 4 and Annex II.
EU European Green Bond Standard	Environmental additionality	Low	The framework strengthens eligibility, allocation and review, but it does not impose a binding counterfactual additionality test or minimum new-activity threshold. Source: Regulation (EU) 2023/2631, Art. 4 and Recital 16.
ICMA Green Bond Principles	External review / verification	Medium	External review is recommended to assess alignment with the four core components, and reviewers are encouraged to disclose credentials and expertise, but review is not mandatory. Source: ICMA Green Bond Principles 2025, External Reviews section.
ICMA Green Bond Principles	Supervision / sanctions	Low	The Principles are voluntary process guidelines and do not create legal rights, liability or a dedicated supervisory regime. Source: ICMA Green Bond Principles 2025, Disclaimer.
ICMA Green Bond Principles	Refinancing governance	Medium	Where proceeds are used for refinancing, issuers are recommended to disclose the estimated financing/refinancing split and, where relevant, the look-back period for refinanced eligible projects. Source: ICMA Green Bond Principles 2025, Use of Proceeds section.
ICMA Green Bond Principles	Environmental additionality	Low	The Principles require eligible green projects to provide clear environmental benefits, but they do not require proof of incremental environmental benefits beyond business-as-usual financing. Source: ICMA Green Bond Principles 2025, Use of Proceeds section.
Japan Green Bond Guidelines	External review / verification	Medium	External review is not a hard-law requirement, but the guidelines provide detailed expectations for reviewer integrity, competence and avoidance of misleading or predetermined conclusions. Source: Japan Green Bond and Sustainability-Linked Bond Guidelines 2024, Green Bond Guidelines, Code of Conduct for External Reviewers.
Japan Green Bond Guidelines	Supervision / sanctions	Low	The guidelines are non-binding and do not establish a public supervisory authority or sanctions regime for the green-bond label. Source: Japan Green Bond and Sustainability-Linked Bond Guidelines 2024, Introduction/Disclaimer.
Japan Green Bond Guidelines	Refinancing governance	High	The guidelines explicitly distinguish refinancing from new financing, discuss the different environmental additionality of refinanced projects, and encourage disclosure of project age and remaining useful life for repeated refinancing. Source: Japan Green Bond and Sustainability-Linked Bond Guidelines 2024, Section 2, Guidance point 4.
Japan Green Bond Guidelines	Environmental additionality	Medium	The guidelines explicitly mention environmental additionality in the refinancing context and encourage issuers to disclose when new projects represent a larger share than refinancing, but they do not impose a binding counterfactual test. Source: Japan Green Bond and Sustainability-Linked Bond Guidelines 2024, Section 2, Guidance point 4.
ASEAN Green Bond Standards	External review / verification	Medium	Appointment of an external reviewer remains voluntary, but when review is used, reviewer expertise, credentials and review scope must be made publicly accessible. Source: ASEAN Green Bond Standards 2018, Section 5.
ASEAN Green Bond Standards	Supervision / sanctions	Low	The standards create a regional label and eligibility restrictions, but do not establish a dedicated supranational supervisory authority or sanctions regime. Source: ASEAN Green Bond Standards 2018.
ASEAN Green Bond Standards	Refinancing governance	Medium	Issuers are recommended to disclose the financing/refinancing split and clarify, where relevant, the look-back period for refinanced eligible green projects. Source: ASEAN Green Bond Standards 2018, Section 4.1.4.
ASEAN Green Bond Standards	Environmental additionality	Low	Eligible green projects must provide clear environmental benefits assessed and quantified by the issuer where feasible, but no counterfactual additionality mechanism is required. Source: ASEAN Green Bond Standards 2018, Section 4.1.3.
China Catalogue + Green Bond Principles	External review / verification	Medium	Issuers are suggested to engage independent third-party evaluation and certification agencies, and are encouraged to disclose external review reports during the life of the green bond. Source: China Green Bond Principles 2022, Sections 2.2 and 2.4.3.

Framework	Credibility mechanism	Code	Evidence anchor and source
China Catalogue + Green Bond Principles	Supervision / sanctions	Medium	The framework operates within a state-linked market-governance environment, with catalogue-based eligibility and general bond-market oversight, but without a dedicated green-label sanctions regime comparable to the EU model. Source: Green Bond Endorsed Projects Catalogue 2021; China Green Bond Principles 2022.
China Catalogue + Green Bond Principles	Refinancing governance	Low	Proceeds may be used for construction, operation, acquisition, working capital and repayment of interest-bearing debts of green projects, but the framework does not provide a dedicated refinancing-share disclosure rule, look-back period or asset-age disclosure requirement. Source: China Green Bond Principles 2022, Section 2.1.
China Catalogue + Green Bond Principles	Environmental additionality	Low	The framework defines eligible green projects and requires impact-calculation standards and methods, but it does not impose a counterfactual additionality test. Source: Green Bond Endorsed Projects Catalogue 2021; China Green Bond Principles 2022, Sections 2.1 and 2.2.1.
India Sovereign Green Bond Framework	External review / verification	Medium	The framework was reviewed by CICERO through a second-party opinion, and the Government of India states its intention to engage a third-party external reviewer for annual assessment of allocation alignment. Source: India Sovereign Green Bond Framework 2022, Section 3.
India Sovereign Green Bond Framework	Supervision / sanctions	Medium	Credibility is structured through a Green Finance Working Committee, project selection and evaluation procedures, and review of proceeds allocation, but no dedicated market-wide sanctions regime is created. Source: India Sovereign Green Bond Framework 2022, Sections 2.2 and 2.3.
India Sovereign Green Bond Framework	Refinancing governance	Medium	Proceeds may finance or refinance eligible green expenditures, and a separate account is maintained by the Ministry of Finance to support transparent proceeds allocation and accounting. Source: India Sovereign Green Bond Framework 2022, Sections 2.1 and 2.3.
India Sovereign Green Bond Framework	Environmental additionality	Low	Project selection is based on eligible categories and evaluation by relevant ministries or departments, but the framework does not require a counterfactual test of incremental environmental benefit. Source: India Sovereign Green Bond Framework 2022, Section 2.2.
China Sovereign Green Bond Framework 2025	External review / verification	High	The Ministry of Finance engaged Lianhe Green Development and DNV Business Assurance for second-party opinions and commits to independent external verification of annual sovereign green-bond information disclosure. Source: PRC Sovereign Green Bond Framework 2025, Section 2.5.
China Sovereign Green Bond Framework 2025	Supervision / sanctions	Medium	The Ministry of Finance is responsible for project evaluation and selection, establishing the Green Expenditures List, annual disclosure and periodic review of green expenditures, but the framework does not create a separate sanctions schedule. Source: PRC Sovereign Green Bond Framework 2025, Sections 2.2–2.5.
China Sovereign Green Bond Framework 2025	Refinancing governance	High	Proceeds may be allocated to eligible green expenditures in the issuance year, the following fiscal year and up to three previous fiscal years; at least half of proceeds must be allocated to expenditures in the current and next fiscal year. Source: PRC Sovereign Green Bond Framework 2025, Sections 2.1 and 2.3.
China Sovereign Green Bond Framework 2025	Environmental additionality	Medium	The framework excludes green expenditures already financed by dedicated revenue or financing sources, expenditures of other government agencies and expenditures financed by local government bonds supporting sustainable development. These are additionality-adjacent safeguards but not a counterfactual test. Source: PRC Sovereign Green Bond Framework 2025, Section 2.1.

Note. Codes correspond to the High/Medium/Low institutional-intensity classifications reported in the main manuscript. Evidence anchors are drawn from the primary framework documents.