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Navigating the green transition: a comparative analysis of green building policy frameworks in China, the EU, and the US using structural topic modeling

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Against the backdrop of escalating global climate change challenges, the green transition of the building sector has emerged as a core agenda. However, how the distinct governance models of major economies shape unique policy paths and whether these paths are converging over the long term remains underexplored through systematic, data-driven empirical research. To fill this gap, this study employs the structural topic model method for a quantitative analysis of 206 national-level green building policy documents issued by China, the European Union, and the United States from 2000 to 2024. Our analysis reveals three distinct policy pathways. China employs a planning-driven model focused on national goals and technical standards. The EU utilizes a supranational, regulatory integration model centered on legally binding directives and nearly zero-energy building targets. In contrast, the US follows a market-incentive federalist model dominated by financial instruments like tax credits and subsidies. Despite these divergent approaches, we find emerging convergence on two key tools: building energy codes and residential subsidies. This study contributes a data-driven, dynamic framework for comparative policy analysis, revealing strategic divergences and convergences among key global actors. The findings offer empirical insights for policy design, cross-national learning, and international cooperation in accelerating green building transition.

KEYWORDS

green building, environmental policy, comparative governance, structural topic modeling, policy instruments

1 Introduction

1.1 The green challenge in the construction sector and the global response

In the global effort to combat climate change, the green transition of the construction industry has emerged as a decisive and critical domain (Karakosta and Papathanasiou, 2025). Authoritative research indicates that the full life-cycle carbon emissions of

buildings—encompassing the entire process from material production, transportation, and construction to building operation and demolition—account for approximately 36% of global final energy consumption and nearly 40% of total energy-related carbon emissions (Le et al., 2023). This substantial environmental footprint is rooted in complex socioeconomic activities, primarily driven by sustained economic growth, rapid urbanization, and a corresponding surge in energy demand (Gonzalez-Torres et al., 2025). The complexity of the issue lies not only in the direct energy consumption during the operational phase but also in the “embodied carbon” associated with the manufacturing of building materials and the construction process itself, which constitutes an increasingly significant portion of a building’s life-cycle carbon footprint (Palomar-Torres et al., 2025). The production of mainstream materials like concrete and steel, in particular, is a primary source of embodied carbon (Chen et al., 2022), making the decarbonization of the supply chain an indispensable component of the industry’s green transition.

To address this formidable challenge, promoting green buildings, which cover the full life-cycle and consider both operational and embodied carbon, has become a global consensus and a core solution (He, 2022). However, despite the demonstrable benefits of green buildings in energy savings, emission reductions, improved indoor environmental quality, and enhanced asset value, their spontaneous market adoption is still impeded by multiple barriers. These include high initial investment costs, information asymmetry among market participants, and a lack of uniform technical standards (Warren-Myers et al., 2024). The existence of these market failures underscores the absolute necessity of robust public policy intervention. More urgently, the relationship between climate change and the construction sector is not unidirectional but forms a self-reinforcing vicious cycle: climate change leads to more frequent extreme weather events, which in turn increases the heating and cooling demands of buildings, thereby driving up energy consumption and carbon emissions and further exacerbating climate change (Duan et al., 2025). Breaking this cycle is the central task in advancing a sustainable transition for the construction sector.

Consequently, the world’s major economies have placed the green transition of the construction sector at the core of their national energy and climate strategy agendas. The European Union (EU), for instance, systematically promotes the enhancement of building energy efficiency across the region through its continuously updated Energy Performance of Buildings Directive (EPBD) (Maduta et al., 2023), notably by establishing stringent “nearly zero-energy” targets for new constructions (Aram et al., 2022). These policy interventions are critical not only for overcoming market barriers but also because empirical research has demonstrated that the large-scale development of green buildings can effectively reduce a region’s overall carbon intensity (Kim et al., 2022), serving as a potent tool for nations to meet their carbon neutrality commitments. Therefore, a systematic understanding and comparison of the policy frameworks of major global actors are of paramount importance for accelerating the green transition of the global construction industry.

1.2 Defining the research problem: from policy existence to pathway divergence

The academic community has undertaken valuable explorations of green building policies in major economies, such as in-depth assessments of the EU’s EPBD framework (Sesana et al., 2024). These studies have established a fundamental fact: major global actors have recognized the necessity of policy intervention and have taken action. However, as research deepens, scholarly attention is shifting from the question of whether policies exist to a more profound issue: how these policies differ. Existing cross-national comparative studies still suffer from significant limitations in revealing these fundamental differences.

First, regarding methodology, existing comparisons predominantly rely on qualitative analysis. While qualitative methods can provide deep case-specific insights (Sesana et al., 2024), they prove inadequate for processing large-scale policy texts and analyzing complex policy interactions. As Spyridaki and Flamos noted in a methodological review on energy and climate policy evaluation, traditional qualitative assessments struggle to systematically reveal the complete picture of large-scale policy portfolios, and academia urgently needs new methodological frameworks that integrate the advantages of quantitative analysis (Spyridaki and Flamos, 2014). This view has been echoed in assessments across related fields, with many scholars emphasizing the necessity of using large-scale quantitative data for policy analysis (Wang and Xing, 2022). Second, from an analytical perspective, existing research often focuses on single policy instruments, such as building codes or fiscal incentives, while overlooking the synergistic and counteracting effects among them. To understand complex policy systems, it is imperative to adopt a “policy mixes” perspective, analyzing all policies within a specific domain as an interacting whole (Jordan and Huitema, 2014). This analytical framework has proven effective in fields like renewable energy (Meus et al., 2022) but remains rare in cross-national comparisons of green building policy. Finally, concerning the temporal dimension, many comparative studies provide only a “static snapshot” of policies, failing to capture their long-term evolutionary paths and shifts in focus. Yet, any major sustainable transition is a long-term, dynamically adjusted policy process (Arias et al., 2023). Therefore, to truly understand the differences in the green building policy frameworks of China, the EU, and the US, one must not only examine their current state but also trace their developmental trajectories over the past 2 decades.

In summary, while existing research provides a valuable foundation for understanding green building policy, significant gaps remain in terms of methodology (a bias toward qualitative approaches), analytical perspective (a focus on single instruments), and temporal dimension (a lack of dynamic evolution). Consequently, our understanding of the overall landscape, the similarities and differences, and the underlying governance logic of the green building policy frameworks of the world’s major economies remains fragmented and lacks a systematic, objective, and dynamic perspective. To address this research gap, the focus of this paper will move beyond a simple inventory of policies to answer a set of more in-depth questions.

1.3 Case selection and core research questions

To address the aforementioned research gaps, this study selects China, the EU, and the United States (US) as the subjects for comparative analysis. These three entities are not only the world's largest economies and construction markets but are also geopolitical forces playing pivotal roles in global industrial policy and the sustainable transition agenda (Hauge et al., 2025). Particularly in the field of low-carbon energy transition, comparing the policies of China and the US—the two largest global energy consumers and carbon emitters—has long been a focal point of academic inquiry (Compston and Bailey, 2016). This study incorporates the EU into the comparative framework to provide a more comprehensive global perspective.

The primary rationale for selecting these three actors is that they represent three typical and influential governance paradigms on a global scale: the state-led model, represented by China (characterized by the macro-level goals of its national “Five-Year Plans” and the implementation of national standards like the “Three-Star Certification”); the market-driven federalist model, embodied by the US (which relies more heavily on market-based financial incentives and private voluntary standards like LEED); and the rule-based supranational regulatory model of the EU (which centers on using legally binding directives, such as the EPBD, to coordinate its internal market) (Xu, 2022). This inherent divergence in their models makes a comparative study highly valuable from a theoretical standpoint. Specifically, China's policymaking exhibits typical top-down and government-led characteristics, often utilizing pilot projects and demonstration zones to drive policy innovation (Hu and Lin, 2022), making it an ideal case for studying the state-led governance model. The EU, with its unique supranational governance structure, plays a key role in global climate governance, and its policy influence often radiates worldwide through the export of norms and standards (Kaivo-oja et al., 2016), representing a rule-oriented governance approach. Comparing the public policies of China, the EU, and the US has already become a frontier paradigm for understanding the evolution of global technology governance. In fields such as artificial intelligence and data governance, existing research has successfully employed computational methods like machine learning to reveal the distinct policy priorities and pathways of the three entities (Bisson et al., 2023). This study, for the first time, systematically applies this established comparative framework and cutting-edge analytical methodology to the critical domain of green building.

Therefore, by systematically analyzing the national-level green building policy texts of China, the EU, and the US, this paper aims to answer the following three core research questions (RQs):

1. RQ1: What are the core themes that constitute the green building policy frameworks of China, the EU, and the US?
2. RQ2: What systematic differences exist in the strategic priorities of the three policy frameworks, and how do these differences reflect their respective governance models?
3. RQ3: Over the past 2 decades, what trends have characterized the policy evolution of the three entities, and are there any policy areas showing signs of convergence?

1.4 Methodological approach and contributions

To conduct a systematic analysis of large-scale policy texts, this study employs probabilistic topic models from the field of computational text analysis (Blei, 2012). This approach allows for the automated discovery of latent thematic structures within vast amounts of unstructured text. Specifically, this research utilizes the Structural Topic Model (STM). Unlike the traditional Latent Dirichlet allocation (LDA) model, STM permits the incorporation of text metadata—in this case, the country and year of publication—as covariates in the model. This enables a systematic examination of how the prevalence of policy themes varies as a function of these external variables (Roberts et al., 2014). As a cutting-edge text analysis tool, STM has been successfully applied to analyze decades of literature evolution in various fields, including finance (Ardia et al., 2024), demonstrating its robust capability in processing and interpreting large-scale dynamic textual data. Its covariate analysis feature provides a unique advantage in cross-national comparative research, effectively revealing systematic differences in discursive focus among different actors (Shieh, 2017).

This study aims to make a threefold contribution to both academia and policymaking. First, on a theoretical level, this research answers the scholarly call for employing data-driven methods to analyze and construct policy frameworks (de Curtò et al., 2025). For the first time, it provides a large-scale, dynamic, and empirically supported comparative analysis framework for the field of global green building governance. Although some scholars have attempted to offer theoretical frameworks for green building policy analysis (Li et al., 2021), these are often based on qualitative case studies. In contrast, the framework constructed in this study is derived entirely from the quantitative analysis of large-scale official policy texts, thereby achieving a breakthrough in objectivity and systematicity. Second, our methodological contribution lies in the systematic application of an advanced computational text analysis method to the macro-level comparative study of green building policies. While text mining techniques have already shown potential in micro-level applications such as decision support in green building (Xiao et al., 2017), their use as a tool for large-scale, dynamic, and cross-national policy comparison represents a novel endeavor. This methodological extension aligns with current frontier explorations that use text data to map technological innovation trajectories in the construction industry (Xue et al., 2024) and elevates this paradigm from the “technical” to the “policy” level. Finally, the practical contribution of this study is to provide policymakers with a valuable “policy map” by systematically revealing the strategic differences, path dependencies, and emerging points of convergence in green building policy among China, the EU, and the US. This can assist decision-makers in engaging in transnational learning and adaptation when designing future policies to more effectively advance the green economic transition (Sancak, 2023). The findings of this research offer a crucial empirical foundation for “policy learning” and “policy transfer” (Goyal and Howlett, 2021), providing clear guidance for identifying the most promising areas for international cooperation, particularly in addressing the global crisis of climate change.

2 Literature review

2.1 The state of green building policy research

A substantial body of academic literature has been amassed on green building policy, which can be broadly categorized into three levels. At the micro-level, extensive research has been dedicated to analyzing specific policy instruments. For instance, concerning fiscal incentives, scholars have employed models such as evolutionary game theory and system dynamics to conduct detailed assessments of the effectiveness and financial feasibility of tools like subsidies, tax credits, and floor area ratio bonuses (Fan and Li, 2025; Jiang et al., 2022). There are also systematic reviews of how various incentive policies impact the economic viability of green buildings (Li et al., 2023). In the realm of mandatory standards, research not only covers the development and enforcement mechanisms of building energy codes (Aydin, 2024) but also delves into the micro-level assessment of how specific technical choices, such as building envelope materials, comply with national regulations (Albarssi et al., 2024). Furthermore, voluntary certification systems, represented by Leadership in Energy and Environmental Design (LEED) and Building Research Establishment Environmental Assessment Method (BREEAM), have been subject to in-depth critical reflection, with studies examining performance evaluation issues during the post-certification operational phase (Awolesi and Reams, 2025) and exploring cutting-edge integrations with digital technologies like Building Information Modeling (BIM) (Ur Rehman et al., 2023).

At the meso-level, research focusing on the policy evolution within specific countries or regions is also well-established. Studies on China have deeply analyzed the role and challenges of its “Three-Star” green building rating standard in the industry’s transformation (He et al., 2023) and have explored issues like supply chain management from the micro-perspective of market actors (Cai et al., 2023), offering a panoramic overview of the development of green real estate in the country (Ren and Kim, 2023). Research on the United States has highlighted the “bottom-up” and polycentric governance features of its policymaking, emphasizing the crucial roles of local governments and market signals (Chen and Gou, 2023), and has evaluated the effectiveness of the most prominent federal policy, the residential energy efficiency tax credit (El-Hakim and AbouZeid, 2024). Studies on the European Union have concentrated on its core supranational directive, the EPBD, systematically assessing its differentiated implementation progress and outcomes across member states (Tomassi et al., 2024; Marotta et al., 2023; Attia et al., 2023). These country-specific studies provide invaluable case evidence for understanding policy practices within different governance contexts.

At the macro-level, scholars have begun to undertake cross-national policy comparisons. These studies often focus on specific policy instruments; for example, some researchers have conducted detailed textual comparisons of green building rating systems (Li et al., 2023) and building codes (Wang et al., 2024) between China and the US. Additionally, other scholars have compared the conceptual frameworks of building environment assessment methods across different countries (Assefa et al., 2022; Abdelhaleem, 2024). Although limited in scope, these pioneering comparative

studies have laid the groundwork for more systematic and large-scale cross-national policy analysis. In a broader context, cross-national comparisons of the effectiveness of different policy instruments are already a mature research paradigm in the field of energy and environmental policy (Xu et al., 2024). This suggests that applying such systematic comparative analysis to the domain of green building policy is not only feasible but also urgently needed.

2.2 Research gaps and the point of departure for this study

Although existing research provides a solid foundation for understanding green building policy, as outlined in the introduction, it suffers from clear limitations in methodology, analytical perspective, and temporal dimension, which collectively form a significant research gap.

First, existing comparative research is heavily reliant on qualitative analysis and case studies. While these methods can offer profound insights into causal mechanisms (Tomassi et al., 2024), their conclusions often lack generalizability, and they face challenges in processing and comparing large-scale, diverse policy texts. A successful green transition depends on effective policy mixes rather than single instruments, making it crucial to understand the interactions between different policies (Xu et al., 2024). However, existing comparative research on green building lacks the quantitative methodologies needed to systematically analyze these complex policy portfolios.

Second, from an analytical perspective, the current body of research appears fragmented. A large number of studies concentrate on in-depth analyses of single policy instruments (Fan and Li, 2025; Jiang et al., 2022; Albarssi et al., 2024) or on comparing specific rating systems (Li et al., 2023; Wang et al., 2024). While this has undoubtedly deepened our understanding of the individual tools within the “policy toolbox”, this “seeing the trees but not the forest” approach prevents a comprehensive grasp of the overall structure, strategic intent, and priority differences of national policy mixes. Successful policy intervention is typically a carefully designed policy portfolio, not merely a simple aggregation of individual tools (Aydin, 2024). Therefore, there is an urgent need for research that can conduct a holistic and systematic comparison at the macro-framework level.

Finally, concerning the temporal dimension, most comparative studies offer a “static snapshot” of policies—that is, a comparative analysis of policy documents at a specific point in time (Wang et al., 2024)—but fail to capture the long-term evolutionary trajectory of the policy framework as an organic whole. Comparative research in the field of energy transition has shown that different countries exhibit significant variations in their transition pathways and speeds, which are underpinned by long-term policy drivers and processes of institutional change (He et al., 2023). Consequently, to profoundly understand the similarities and differences in green building policy among China, the EU, and the US, a static comparison is far from sufficient. It is imperative to place these policies within a historical context spanning more than 2 decades to examine the dynamic evolution of their focal points.

This absence of a holistic and dynamic comparison of policy frameworks not only limits our theoretical understanding of the

complexity of the global green transition but also, on a practical level, hinders effective policy learning and international cooperation among nations. The present study is designed specifically to systematically address this threefold gap across methodology, perspective, and dimension.

2.3 Text mining as an analytical framework

As previously outlined, existing comparative research relies heavily on qualitative analysis, a method that faces challenges of subjectivity and an inability to systematically reveal the full picture of complex policy mixes when handling large-scale, cross-national policy texts. To overcome these limitations, this study introduces the STM. As a data-driven computational method, STM can systematically process large volumes of unstructured text in a reproducible and quantitative manner, thereby objectively uncovering the thematic structures, strategic differences, and dynamic evolutions hidden within the policy texts. In contrast, computational methods, particularly topic models, offer powerful new tools for systematic “comparative policy analysis” (Bagozzi and Berliner, 2018). Compared to labor-intensive manual coding, topic models can process massive volumes of text data with greater efficiency and reproducibility (Player et al., 2025). The STM employed in this research is an unsupervised text classification method. Its advantage lies in not requiring predefined coding rules; instead, the model discovers themes “bottom-up” from the data itself, making it particularly suitable for the exploratory analysis of policy frameworks (Roberts et al., 2019). STM has demonstrated high scenario adaptability in the field of policy analysis; for example, it can be used not only for the international comparison in this study, but also to analyze the hierarchical structure of policies within a single country (e.g., comparing similarities and differences between central and local policies) or to identify the differing policy demands of various stakeholders (e.g., government, industry, and the public).

The core analytical tool of this study is the STM. STM is an advanced topic model developed from the LDA model. Its key innovation is the ability to integrate document-level metadata as covariates into the analysis (Roberts et al., 2014). For this study, this means we can use “country” (or region) and “year” as covariates to systematically compare the differences among the policy frameworks of the three actors and to track the dynamic evolution of these differences. The covariate analysis capability of STM allows for the precise quantification of the influence of external factors on textual themes (Wu, 2023). Consequently, it has proven to be an effective tool for tracking how policy agendas in specific fields “evolve over time” (Tamakloe and Park, 2023).

The application of STM in this research is grounded in a solid theoretical and practical foundation. First, the research design follows the logic of comparative case study analysis (Gerring and Cojocaru, 2016), treating China, the US, and the EU as archetypal cases representing different governance models. STM provides a robust, quantitative, and data-driven basis for this comparison. Second, the method has been widely applied to the analysis of various policy texts. For example, scholars have used STM for the data-driven construction of government policy frameworks (Guenduez and Mettler, 2023) and for analyzing public discourse on complex issues such as climate change (Wright et al., 2023).

Notably, in fields related to construction and urban planning, STM has also been successfully employed to analyze public opinion in public transportation planning (Chen et al., 2023). Therefore, the systematic application of STM—a cutting-edge and proven method—to the cross-national comparative study of green building policy constitutes the core methodological point of departure for this research.

3 Theoretical framework and comparative context

3.1 Environmental governance models: an explanatory framework

To systematically understand the divergent policy pathways adopted by different political entities in the green building sector, this study draws on core theories of comparative policymaking to construct an analytical framework capable of explaining these differences (Bailey and Karapın, 2025). Successful governance depends not on single policy instruments but on a well-designed “policy mix” (Wu et al., 2024). Therefore, the unit of analysis for this study is the overall national-level policy framework, rather than isolated regulations or subsidies. Green building policy is a clear manifestation of the “environmental policy integration” (EPI) concept, as it inherently requires the integration of environmental and climate objectives into traditional construction, urban planning, and economic policies (Jensen et al., 2023). Understanding how different nations achieve this integration is one of the key goals of this research. Based on the existing literature, this study delineates three ideal-type environmental governance models to serve as an explanatory framework for the subsequent data analysis.

The first is the state-led model. China’s environmental governance system can be clearly defined as a “state-led, top-down” model, in which the central government is responsible for formulating macro-strategies and targets, while local governments play a crucial role in implementation (Yang et al., 2024). A prominent feature of this model is “experimentalism” governance, where the central government often tests new policies by establishing pilot cities or demonstration zones, with successful experiences subsequently being summarized and scaled up nationwide (Wang et al., 2024). The formidable implementation capacity of this model relies heavily on the state’s direct control over key resources and state-owned enterprises, which enables the effective mobilization of societal forces to achieve strategic green transition goals (Ye et al., 2024).

The second is the supranational regulatory model. The EU’s governance model is a unique system whose core mechanism is “The Brussels Effect” (Tumer and van Zeben, 2025). By establishing stringent standards for access to its internal market, such as those for building energy efficiency, the EU can effectively transform its regulations into global standards that international corporations must adhere to. In global climate governance, the EU has long been regarded as a “rule-maker” and “leader” (Pollex and Berker, 2024), and thus its policy initiatives in the green building sector carry global demonstrative significance. This model is characterized by the use of a legal framework to coordinate multiple sovereign entities, setting uniform regulatory baselines and common collective goals.

The third is the market-driven federalist model. Unlike the other two, the US governance model is fundamentally “market-driven”, with the federal government’s role being more focused on guiding private sector investment and innovation by creating market signals and providing fiscal incentives, rather than through direct mandatory interventions (Uz and Mamkhezri, 2024). A key to understanding the US model is its “federalism” structure (Lecours and Beland, 2022). Much of the authority for mandatory building codes actually resides with state and local governments, while the federal level concentrates more on inducement through tools like tax credits, resulting in a polycentric and sometimes fragmented governance landscape. The US preference for market-based incentive tools is supported by a strong theoretical and empirical foundation, as numerous studies have shown that well-designed fiscal incentives can promote technological transitions at a lower social cost (Kocakusak et al., 2024). At the same time, establishing nationally uniform mandatory environmental standards in the US faces complex political resistance and a process fraught with bargaining among multiple interests, which partly explains why its policy framework leans more towards non-mandatory incentive measures (Lang, 2025).

3.2 Green building governance contexts in China, the EU, and the US

The aforementioned theoretical models are clearly reflected in the specific policy domain of green building. The development of green buildings in China has not been a purely spontaneous market process but has rapidly advanced under strong state policy guidance and strategic planning (Hu and Lin, 2022). The continuity and strategic nature of its policies are centrally embodied in the “Five-Year Plan” system. Since the 11th Five-Year Plan (2006–2010), building energy conservation and green buildings have consistently been key components of the national medium- and long-term development agenda, providing clear and stable policy signals to the industry (Song et al., 2022). To translate these macro-plans into practice, the Chinese government has established its own national “Green Building Evaluation Standard” (i.e., the “Three-Star Certification” system), which serves as the primary technical tool for assessing and incentivizing green building projects (Li et al., 2023). This certification system is not merely a technical standard but also a significant governance instrument used to guide the market, promote technological progress, and reinforce the government’s leading role in the sustainable transition of the construction sector (Goubran et al., 2023).

The EU’s green building governance framework is constructed around its core legislation, the EPBD. This directive sets uniform energy efficiency targets and a policy framework for all member states, aiming to harmonize the entire EU internal market (Attia et al., 2023). This supranational regulation is manifested as a form of multi-level governance: legally binding, top-level directives are formulated at the EU level and are then transposed by each member state into specific national policies and action plans according to their domestic contexts, such as developing long-term building renovation strategies and promoting energy performance certificates (EPCs) (Ascione et al., 2022). As a key market-based regulatory tool within the EPBD framework, EPCs

provide transparent energy information to the real estate market by rating the energy efficiency of buildings, thereby guiding market preferences (Beltran-Velamazan et al., 2025). The EU’s governance model also exhibits dynamism and foresight, as its core directive, the EPBD, is periodically “recast” to incorporate the latest technological advancements and address emerging climate challenges (Giordano and Andreotti, 2023).

The green building market in the United States is, to a large extent, shaped by a non-governmental, voluntary standard: LEED (Davis et al., 2023). In contrast to the government-led standard systems in China and the EU, the primary policy levers for the US federal government to promote green buildings are market-based fiscal incentives, with tax credits for residential and commercial buildings being one of the most central and enduring tools. This approach aims to indirectly achieve policy objectives by influencing the economic decisions of market actors. The country’s federal structure dictates the “polycentric” nature of its green building governance, as many significant policy innovations originate not at the federal level but are driven “bottom-up” by pioneering cities and state governments (Brandtner, 2022). Consequently, the US green building policy system is a complex network composed of policies at the federal, state, and local levels. Its uniqueness also lies in its heavy reliance on “private regulation”. Voluntary standards like LEED, propelled by strong market demand and industry associations, have effectively filled the void left by a lack of mandatory federal regulations, typifying a “private regulation” governance model (Shang et al., 2023).

4 Data and methods

4.1 Policy text collection and corpus construction

The empirical basis of this study is a purpose-built corpus of national-level green building policy texts from China, the US, and the EU. To ensure the authoritativeness and comparability of the data, all texts were sourced from official channels. The policy documents for China were obtained from the “pkulaw.com” legal database. For the European Union, texts were sourced from its official law portal, “EUR-Lex” (eur-lex.europa.eu). The policy texts for the United States were retrieved from the official platform of the U.S. Government Publishing Office, “GovInfo” (www.govinfo.gov). The time frame of this study (2000–2024) is based on the following considerations: the period around 2000 was the nascent stage for global green building policy, including, for example, the early deliberation of the EU’s Energy Performance of Buildings Directive (EPBD), the launch and initial promotion of the US LEED standard, and China’s initial systematic focus on building energy conservation in preparation for the Olympic Games. Selecting 2000 as the starting point allows for a complete capture of the critical development phase for all three economies, from policy formation to systematic maturation.

To ensure the comprehensiveness of the retrieval, this study designed a set of keyword combinations covering the core concepts of the field, including “green building”, “energy conservation in buildings”, “energy efficiency in buildings”, “sustainable buildings”, “building decarbonization”, and “nearly zero-energy buildings”.

TABLE 1 Composition of the policy document corpus.

Region	Data source	Time frame	Number of policy texts
China	Pkulaw	2000–2024	70
European union	EUR-lex	2000–2024	49
United States	GovInfo	2000–2024	87
Total	—	—	206

During the search process, these keywords were adapted and adjusted according to the specific features and common parlance of each database.

After an initial retrieval yielded a large volume of raw texts, this study followed a stringent filtering protocol to construct the final analytical corpus. The core principles for selection were to ensure hierarchical equivalence and substantive content. Specifically, we excluded all documents lacking legal or national strategic binding force, such as procedural notices, press releases, meeting minutes, and local-level (province/state/city) regulations. For China, only laws, administrative regulations, and national-level plans issued by the central government were retained; for the US, only final bills passed by Congress and signed by the President, as well as executive orders, were kept; and for the EU, regulations and directives with universal binding force on all member states were selected. Through this process, a final corpus consisting of 206 core policy documents was established, providing a solid empirical foundation for the subsequent STM analysis. The specific composition of the corpus is detailed in the table below (Table 1).

4.2 Application of the STM

This study employs the STM to analyze the policy text corpus. As an advanced probabilistic topic model, STM builds on the foundational principles of LDA, which treats each document as a probability distribution over multiple topics, and each topic, in turn, as a probability distribution over multiple words (Blei, 2012). The core advantage of STM lies in its ability to incorporate document metadata—in this study, “region” and “year”—as covariates into the model, thereby enabling a systematic estimation of the influence of these external factors on topic prevalence (Roberts et al., 2014).

Specifically, STM allows the prevalence of topics to vary according to document-level covariates, rather than assuming a common prior distribution across all documents. This feature makes STM an ideal tool for answering this study’s core research questions. Specifically, STM allows the prevalence of topics to vary according to document-level covariates—in this case, “region” and “year”—an approach that provides more intuitive interpretations:

1. The “region” covariate: In simple terms, by incorporating “region” (China, EU, US) as a covariate, the model can automatically estimate and compare the average proportion of the same topic (e.g., “tax credits”) within the policy agendas of the three actors. This allows us to statistically quantify the systematic differences in thematic focus.

2. The “year” covariate: By using “year” as a continuous covariate, the model can further track the dynamic trajectory of that topic’s prevalence over time, revealing its rise or fall over the past 2 decades.

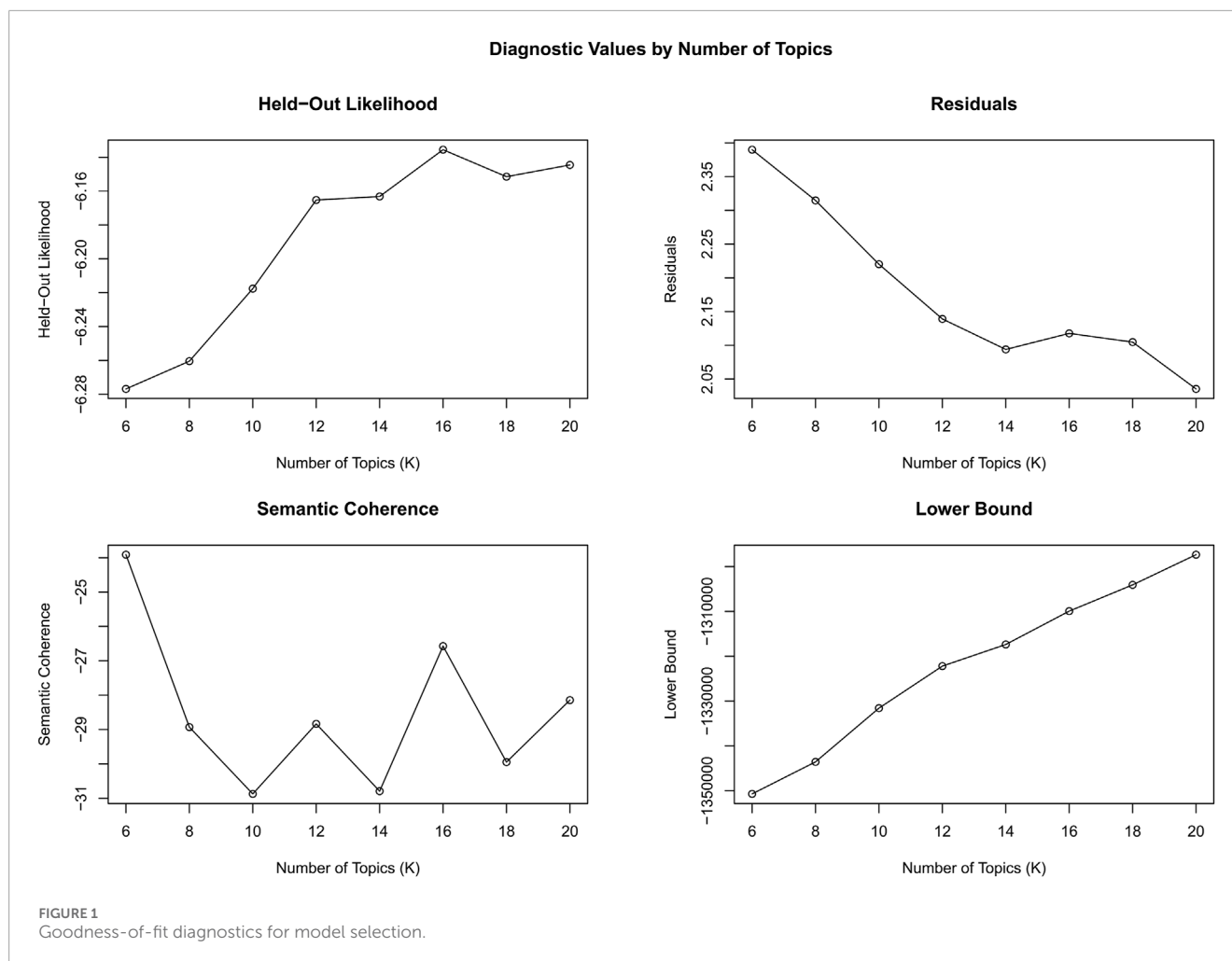
This capacity to integrate textual content analysis with external variables allows STM not only to identify what policy texts say but also to explore “who focused more on what and when”, thus providing powerful analytical support for cross-national and dynamic policy comparison (Wang et al., 2025). All analyses in this study were performed using the stm package in the R programming language (Roberts et al., 2019).

4.3 Text preprocessing and selection of the number of topics (K = 16)

Prior to topic modeling, the raw corpus underwent a standardized text preprocessing procedure. This process was designed to remove noise from the text while preserving core semantic information. The specific steps included: removing numbers, punctuation, and custom stopwords (i.e., words like “building” and “policy” that are ubiquitous across all texts but do not help in differentiating topics); converting all English words to lowercase; and applying stemming to English words to consolidate terms with a common root. Furthermore, to enhance the model’s efficiency and stability, this study removed rare terms that appeared in less than 5% of the total documents in the corpus.

The selection of the number of topics (K) is a critical decision in the topic modeling process, one that requires balancing the model’s statistical fit with the human interpretability of the results (Hollibaugh, 2019). This study adopted a hybrid approach that combined data-driven diagnostics with expert judgment. First, we ran multiple models with K values ranging from 6 to 20. Following established practice, we calculated a series of diagnostic metrics, with a particular focus on semantic coherence (ensuring words within a topic are related) and exclusivity (ensuring topics are distinct) as key indicators of model quality (Dwivedi et al., 2023). As illustrated in Figure 1, the diagnostic plot visually demonstrates that K = 16 represents the “elbow point” achieving the optimal balance between these two metrics—it exhibited both high semantic coherence and strong exclusivity, thus being identified as the statistically optimal choice.

After establishing K = 16 as the statistically optimal option, the research team conducted an in-depth manual evaluation of the topics generated by this model. This was to ensure that the



high-frequency words and representative documents under each topic possessed a clear, consistent, and domain-relevant semantic meaning. To further validate the model's quality, this study also examined the posterior probability distribution of the topics across the documents (see Figure 2). The results showed that the vast majority of topics were highly concentrated within a small number of documents, which aligns with the fundamental assumptions of topic modeling, thereby reconfirming the rationality and robustness of selecting $K = 16$ as the final number of topics.

5 Results

5.1 The 16 core themes of green building policy

Through a STM analysis of the corpus containing 206 policy texts, this study identified 16 core themes that constitute the green building policy frameworks of China, the EU, and the US. These themes are defined by a series of high-frequency co-occurring keywords and are highly associated with specific representative policy documents. The table below (Table 2) details each theme's ID, name, eight most representative keywords, and a typical policy

document. Together, these themes reveal the core issues and policy instruments that the three actors focus on in promoting the green transition of the construction industry.

Topic 1: Directive & Performance Frameworks. This theme primarily concerns the legally binding directives at the EU level and the performance requirements imposed on member states. Keywords such as “direct”, “member”, “state”, and “perform” clearly point to the EU’s unique supranational governance model. Its representative document, the EU’s EPBD, is the core embodiment of this theme, as it establishes a unified framework for building energy efficiency for all member states.

Topic 2: Evaluation & Labeling Systems. This theme focuses on the evaluation standards and certification labels for green buildings. The keywords “evalu”, “label”, and “review” are central to this theme. The representative document, China’s “Administrative Measures for Green Building Evaluation and Labeling”, details the application, review, and management procedures for its national “Three-Star” certification system, reflecting China’s governance approach of guiding the market through national standards.

Topic 3: High-Performance Public Buildings. The policy focus here is on improving the energy efficiency and environmental performance of buildings owned by the federal government. Keywords like “feder”, “agenc”, “school”, and “high-perform” indicate

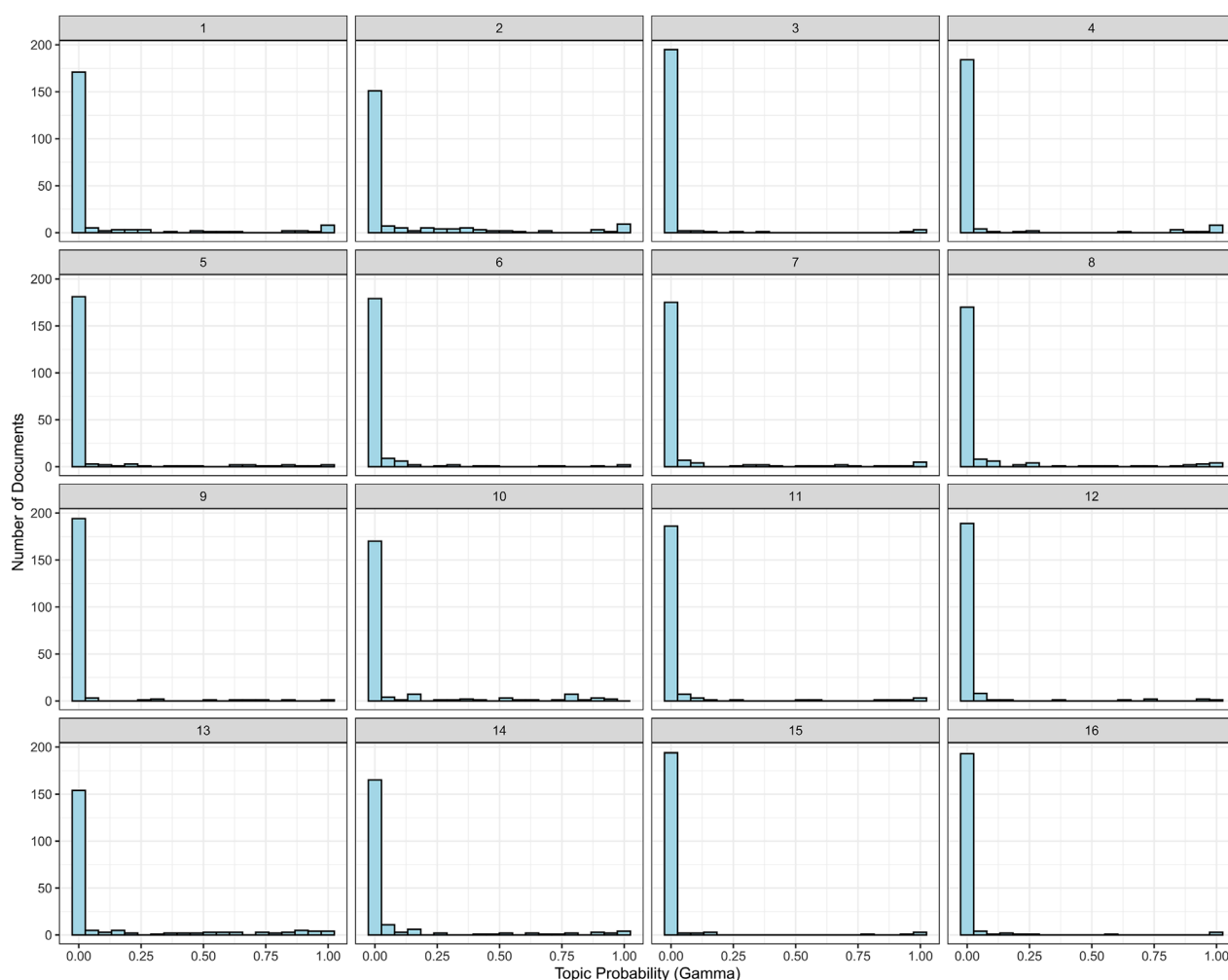


FIGURE 2
Posterior Probability Distribution of Topics across Documents. Note: Each panel represents a topic.

that such policies primarily lead the market through government example. The representative document, the US “High-Performance Green Federal Buildings Act”, requires federal agencies to meet specific green standards when constructing or leasing new buildings.

Topic 4: Commercial Tax Credits & Zones. This theme clearly points to fiscal incentive measures targeting commercial real estate. The keywords “credit”, “properti”, “busi”, and “clean” collectively sketch a policy picture of using tax instruments to guide commercial investment. Its representative document, the US “Clean Energy Business Zones Act”, aims to encourage the development of energy-efficient commercial buildings in designated areas through tax incentives.

Topic 5: NZEB Goals & Requirements. This theme encapsulates the forward-looking building energy efficiency targets set by the EU. Keywords such as “nzeb” (nearly zero-energy building), “requir”, and “epbd” are directly linked to the EU’s core strategy. The representative document, a European Commission report on the progress of Member States towards NZEBs, systematically tracks the policy implementation in each member state toward the goal of “all new buildings being nearly zero-energy buildings”.

Topic 6: Sustainable Infrastructure & Communities. This theme extends the concept of green building from individual structures to the broader level of communities and infrastructure. Keywords like “transport”, “commiss”, and “emiss” demonstrate its cross-disciplinary and comprehensive nature. The representative document, the US “National Capital Environmental and Energy Leadership Commission Act”, aims to coordinate sustainable development within the region, covering multiple aspects including buildings, transportation, and energy.

Topic 7: Green Jobs & Educational Grants. This theme concentrates on the socioeconomic benefits of the green transition, particularly job creation and talent development. Keywords such as “grant”, “loan”, “educ”, and “program” point to the use of public funds to support related training and employment initiatives. The representative document, the US “Green-Collar Youth Employment, Education, and Training Stimulus Act”, is designed to provide educational and employment opportunities for young people to participate in the green economy.

Topic 8: Federal Energy & Water Management. Similar to Topic 3, this theme also focuses on the actions of the federal government

TABLE 2 The 16 core topics of green building policy, with keywords and representative documents.

Topic ID	Topic name	Top 8 keywords	Representative documents
1	Directive & performance frameworks	Perform, member, state, requir, direct, system, european, heat	Directive 2010/31/EU of the european parliament and of the council of 19 May 2010 on the energy performance of buildings (recast)
2	Evaluation & labeling systems	Evalua, label, must, project, construct, manag, applic, review	Comprehensive regulations for the green building evaluation label (2008)
3	High-performance public buildings	Environment, feder, school, high-perform, agenc, section, offic	High-performance green buildings Act of 2007
4	Commercial tax credits & zones	Properti, credit, qualifi, clean, amend, busi, purpos, effici	Clean energy business zone Act of 2011; clean energy empowerment zone Act of 2011
5	NZEB goals & requirements	State, member, requir, perform, epbd, cost, measur, new, nzeb	Report from the commission to the european parliament and the council progress by member states towards nearly zero-energy buildings
6	Sustainable infrastructure & communities	Administr, feder, govern, transport, unit, commiss, emiss, state	National capital region leadership in environmental and energy stewardship commission Act
7	Green jobs & educational grants	Secretari, program, loan, grant, educ, applic	Green-Collar Youth jobs, education, and training stimulus Act
8	Federal energy & water management	Feder, agenc, water, manag, perform, requir	Federal energy and water management performance Act of 2020
9	Residential subsidies & electrification	Elig, project, program, secretari, qualifi, grant, home, electr	Zero-emission homes Act of 2021
10	Renovation wave & industry strategy	Renov, effici, renew, european, sector, commiss, member, product	Communication from the commission ...A renovation wave for europe - greening our buildings, creating jobs, improving lives
11	Building energy codes	Code, standard, effici, secretari, year, model, commerci	To encourage greater energy efficiency in building codes
12	Cross-sectoral policy linkages	Food, program, secur, fuel, leas, global, state	William M. (Mac) thornberry national defense authorization Act for fiscal year 2021
13	National planning & development goals	Construct, conserv, develop, plan, standard, project, implement, promot	Notice on the issuance of the “14th five-year plan for building energy efficiency and green building development”
14	Technical & design standards	Heat, system, design, must, water, standard, thermal, insul	Announcement on the issuance of the industry standard “design standard for energy efficiency of residential buildings in temperate zones”
15	Tax deduction provisions	Properti, effici, deduct, amount, percent, paragraph	Efficient energy through certified technologies (EFFECT) Act of 2003
16	Affordable housing assistance	Effici, hous, standard, program, secretari, assist, requir	Green resources for energy efficient neighborhoods Act of 2008; GREEN Act of 2008

itself but more specifically on the consumption management of energy and water resources. “feder”, “water”, “manag”, and “perform” are its core keywords. The representative document, the US “Federal Energy and Water Management Performance Act”, sets specific energy and water conservation targets for federal agencies.

Topic 9: Residential Subsidies & Electrification. The policy toolkit of this theme is primarily aimed at the residential sector, especially through direct financial subsidies to promote energy

efficiency upgrades and electrification. Keywords like “home”, “grant”, “qualifi”, and “electr” are its main features. The representative document, the US “Zero-Emission Homes Act”, provides subsidies to households for purchasing and installing high-efficiency electric equipment.

Topic 10: Renovation Wave & Industry Strategy. This theme represents the EU’s ambitious strategy for the large-scale energy-efficient renovation of existing building stock. Words such as

“renov”, “european”, “sector”, and “commiss” depict the EU’s policy intent to mobilize the entire construction industry for a systematic transformation. Its representative document, the European Commission’s “A Renovation Wave for Europe”, is the foundational document for this strategy.

Topic 11: Building Energy Codes. This theme centers on mandatory technical standards. Keywords like “code”, “standard”, and “commerci” point to regulatory instruments that set minimum energy efficiency thresholds for new and existing buildings. Its representative document, a bill introduced in the US Congress to encourage the updating of state-level building energy codes, reflects federal efforts to promote the adoption of stricter standards at the local level.

Topic 12: Cross-Sectoral Policy Linkages. The uniqueness of this theme lies in its keywords, which are often related to other policy domains, such as “secur”, “food”, and “global”, indicating that the green building concept is being integrated into broader national strategies. A representative document, the US “National Defense Authorization Act”, which may contain clauses requiring military facilities to meet specific energy efficiency standards, is a typical example of such policy linkage.

Topic 13: National Planning & Development Goals. This theme clearly reflects China’s top-down governance model. Words like “plan”, “develop”, “implement”, and “promot” carry a strong sense of macro-level strategic direction. Its representative document, China’s Special “Five-Year” Plan for Building Energy Efficiency, sets quantitative targets and action roadmaps for the nation’s green building development over a specific period.

Topic 14: Technical & Design Standards. This theme focuses on the specific technical requirements for elements such as building envelopes and heating systems. “design”, “standard”, “heat”, and “insul” are very specific terms, representing the micro-level technical support for implementing macro-level policies. Representative documents include China’s various design standards for energy efficiency in buildings, which provide detailed technical parameters for building design in different climate zones.

Topic 15: Tax Deduction Provisions. Similar to Topic 4, this theme is also about fiscal policy but focuses more on the specific deduction clauses within tax law. Keywords such as “deduct”, “amount”, and “percent” are typical language of fiscal policy. Its representative document, the US “Energy-Efficient Building Incentive Act”, specifies the tax deduction amounts available for buildings that meet certain energy-saving standards.

Topic 16: Affordable Housing Assistance. This theme combines green building with social equity issues, aiming to help low-income groups improve their living conditions and reduce energy costs. Keywords such as “hous”, “assist”, and “program” reflect the social welfare attribute of the policy. Its representative document, the US “Green and Energy-Efficient Neighborhoods Resource Act”, provides dedicated funding for the energy-efficient retrofitting of affordable housing.

To systematically understand the intrinsic logical connections among these 16 themes, in [Section 5.2](#) we analyze their co-occurrence relationships and further group them into four macro policy dimensions: A: Strategic Frameworks & Directives; B: Planning, Standards & Evaluation Systems; C: Governance, Codes & Implementation; and D: Financial Instruments & Support.

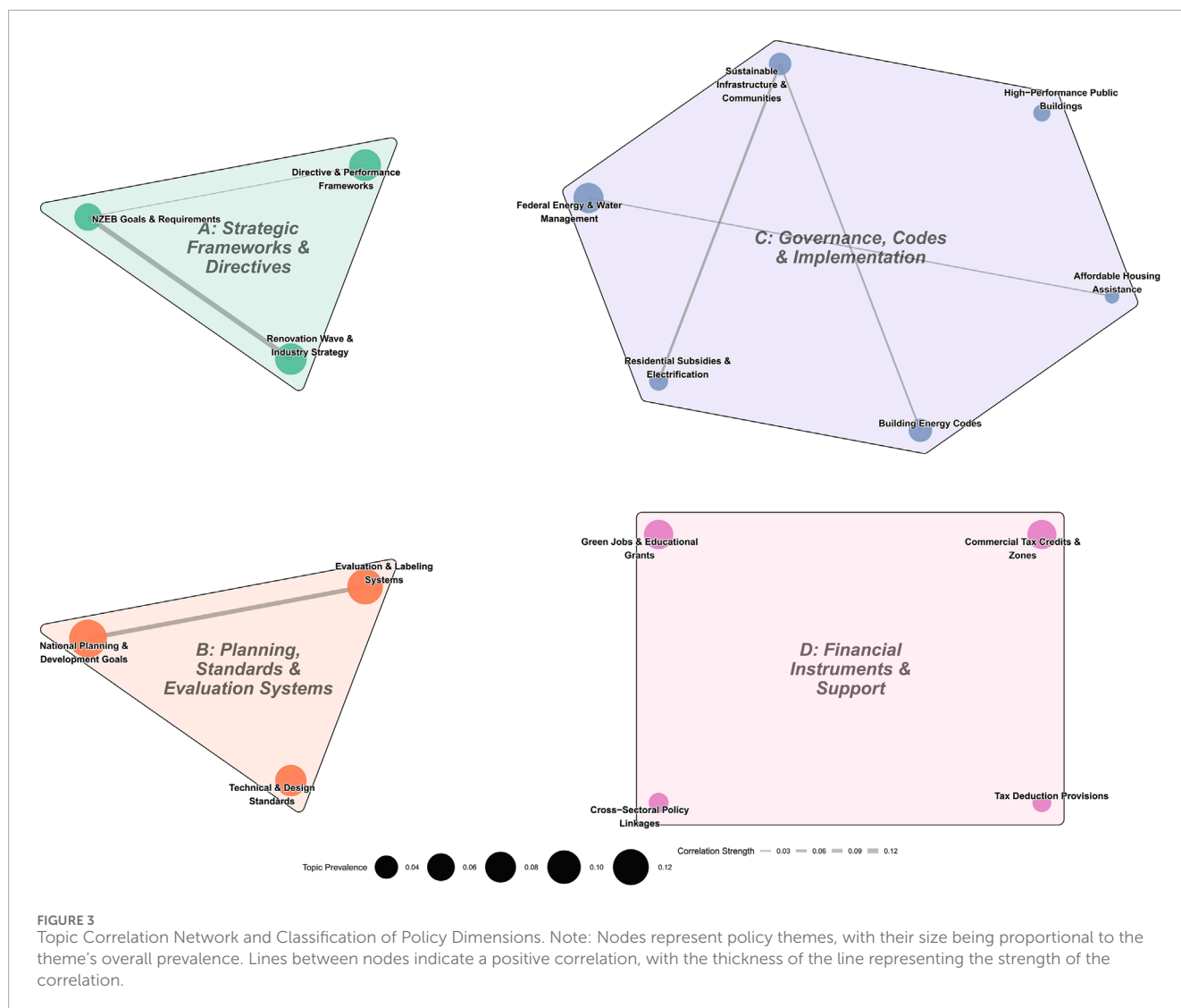
5.2 Structure and overall focus of the policy frameworks

To further understand the intrinsic connections among the 16 policy themes, this study analyzed their co-occurrence relationships within the policy texts. A positive correlation between themes indicates that they tend to be discussed together within the same policy document, thereby revealing the internal logical links of policymaking. Based on the topic correlation analysis and the substantive content of each theme, this study groups the 16 themes into four macro policy dimensions ([Figure 3](#)): A: Strategic Frameworks & Directives; B: Planning, Standards & Evaluation Systems; C: Governance, Codes & Implementation; and D: Financial Instruments & Support. The complete topic correlation matrix heatmap can be found in [Appendix A](#).

As shown in [Figure 3](#), Dimension A: Strategic Frameworks & Directives encapsulates the core of EU policy, comprising Topic 1 (Directive & Performance Frameworks), Topic 5 (NZEB Goals & Requirements), and Topic 10 (Renovation Wave & Industry Strategy). The close connections among these three themes (e.g., a correlation of 0.12 between Topic 5 and Topic 10) indicate that EU policymaking is a highly integrated process, where grand strategic goals (like the “Renovation Wave”) are advanced in synergy with a unified legal framework (the EPBD directive) and clear technical requirements (NZEB). Dimension B: Planning, Standards & Evaluation Systems clearly illustrates the cornerstone of China’s policy framework, consisting of Topic 2 (Evaluation & Labeling Systems), Topic 13 (National Planning & Development Goals), and Topic 14 (Technical & Design Standards). The strong correlation of 0.11 between Topic 2 and Topic 13 empirically reveals China’s governance logic: macro-level national planning (Five-Year Plans) is implemented through specific technical standards and an official evaluation and certification system (the “Three-Star” certification), forming a complete, top-down, closed loop.

Dimension C: Governance, Codes & Implementation covers a broader range of implementation-level issues, including Topic 3 (High-Performance Public Buildings), Topic 6 (Sustainable Infrastructure & Communities), Topic 8 (Federal Energy & Water Management), Topic 9 (Residential Subsidies & Electrification), Topic 11 (Building Energy Codes), and Topic 16 (Affordable Housing Assistance). The connections within this dimension (such as the links between Topic 6 and Topics 9 and 11) highlight the complexity of policy implementation, which requires integrating macro-level community planning with specific energy codes and targeted residential subsidies. Dimension D: Financial Instruments & Support brings together all direct fiscal incentives and supportive policies, including Topic 4 (Commercial Tax Credits & Zones), Topic 7 (Green Jobs & Educational Grants), Topic 12 (Cross-Sectoral Policy Linkages), and Topic 15 (Tax Deduction Provisions). The lack of strong correlations among the themes within this dimension suggests that these financial instruments are often deployed as independent, target-specific policies rather than as a systematic portfolio.

Regarding the overall focus of the policy agenda ([Figure 4](#)), Topic 13, “National Planning & Development Goals”, ranks first with a prevalence of 13.9%, closely followed by Topic 2, “Evaluation & Labeling Systems” (11.8%). The dominant position of these two themes underscores the central importance of national-level



top-down design and standardized evaluation in the entire green building policy agenda. The EU's core policy instruments, such as Topic 1, "Directive & Performance Frameworks" (8.7%), and Topic 10, "Renovation Wave & Industry Strategy" (8.6%), also occupy significant positions. In contrast, specific fiscal incentives, like Topic 9, "Residential Subsidies & Electrification" (2.8%), and Topic 15, "Tax Deduction Provisions" (2.8%), along with social equity-related issues like Topic 16, "Affordable Housing Assistance" (2.3%), receive relatively less overall attention within the policy corpus. This suggests that while financial instruments are crucial in specific contexts, the construction of strategic plans, legal directives, and standard systems remains a higher priority in national-level macro-policy frameworks.

5.3 Cross-national differences and dynamic evolution of policy focus

The core of this research lies in using dynamic data to reveal the systematic differences and evolutionary paths of the green building

policy frameworks of China, the EU, and the US. By incorporating "region" and "year" as covariates into the STM model, we were able to precisely track the changing trajectory of the prevalence (expected topic proportion) of the 16 policy themes within the agendas of the three actors since 2000. The figure below (Figure 5) visually presents this dynamic process, from which three distinct policy paths shaped by different governance models—as well as their subtle interactions and convergences—can be clearly identified.

5.3.1 China's policy profile: a double helix of planning-driven initiatives and standard-setting

China's policy agenda is dominated by a powerful and distinct core: Topic 13 (National Planning & Development Goals). As shown in Figure 5, the attention given to this theme exhibits periodic bursts of growth after 2005, with its peaks corresponding closely to the formulation and promulgation periods of China's 11th (2006–2010) and 12th (2011–2015) Five-Year Plans. This empirically demonstrates that the national five-year plans constitute the "engine" and the source of top-level design for China's green building policy. However, the prevalence of planning is not sustained at a high level;

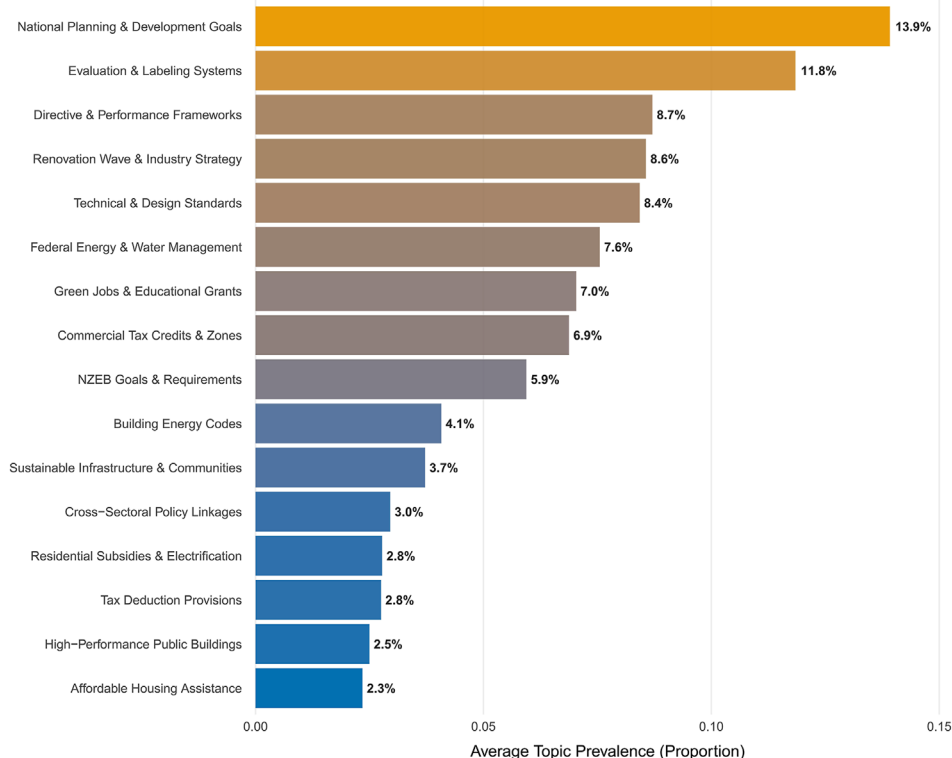


FIGURE 4
Overall Prevalence of Policy Topics. Note: The bar chart shows the average proportion of each topic across all documents.

after a planning cycle is initiated, its prominence in policy texts naturally recedes.

Corresponding to this periodic pulse are two continuously rising supportive curves: Topic 2 (Evaluation & Labeling Systems) and Topic 14 (Technical & Design Standards). The steady, long-term growth of these two themes reveals the internal operational logic of China's governance model: once a macro-level national plan is established, the policy focus shifts to creating and refining the micro-level tools required to implement and measure the plan's objectives. The national "Three-Star" evaluation system (Topic 2) and a series of mandatory design standards covering different climate zones and building types (Topic 14) together form the institutional foundation for translating macro-level "plans" into concrete "projects". This "double helix" structure—in which top-level planning initiates and supporting standards follow—precisely delineates a highly structured, goal-oriented trajectory of policymaking and implementation under China's "state-led" model.

5.3.2 The EU's policy profile: an integrated path of legislative drivers and strategic upgrades

The policy evolution of the European Union is characterized by an integrative approach, founded on core legislation and oriented towards strategic upgrades. The "soul" of its policy framework is Topic 1 (Directive & Performance Frameworks). The trajectory of this theme is not a smooth curve but rather exhibits three distinct peaks that correspond precisely to the three key legislative milestones of the EU's EPBD: its initial adoption in 2002, its first

recast in 2010, and its second recast in 2018. This finding clearly demonstrates that green building governance in the EU is driven by legally binding supranational legislation.

Within the framework of this parent law (the EPBD), specific, forward-looking policy goals are derived. The prevalence of Topic 5 (NZEB Goals & Requirements) began to climb significantly after the 2010 recast of the EPBD formally introduced the NZEB concept, becoming a central issue throughout the 2010s. Entering 2020, with the launch of the European Green Deal, the policy focus was further upgraded. The prevalence of Topic 10 (Renovation Wave & Industry Strategy) rose sharply, signaling a shift in the EU's policy gravity from a focus on new constructions to the more formidable challenge of retrofitting the existing building stock. The synergistic evolution of these three themes powerfully demonstrates the unique path of the EU's "supranational regulatory" model: a foundation is laid through top-level legal directives, which then inform the setting of phased technical goals, and these are ultimately integrated into grander economic and climate strategy initiatives in a progressive and interlinked manner.

5.3.3 The US's policy profile: a dual-track approach of market incentives and federal leadership by example

The policy toolbox of the United States distinctly reflects its "market-driven federalist" hybrid governance model, exhibiting a dual-track characteristic of "incentivizing the market externally while strictly regulating itself internally". On the one hand, its policy agenda shows the highest prevalence across all themes related to

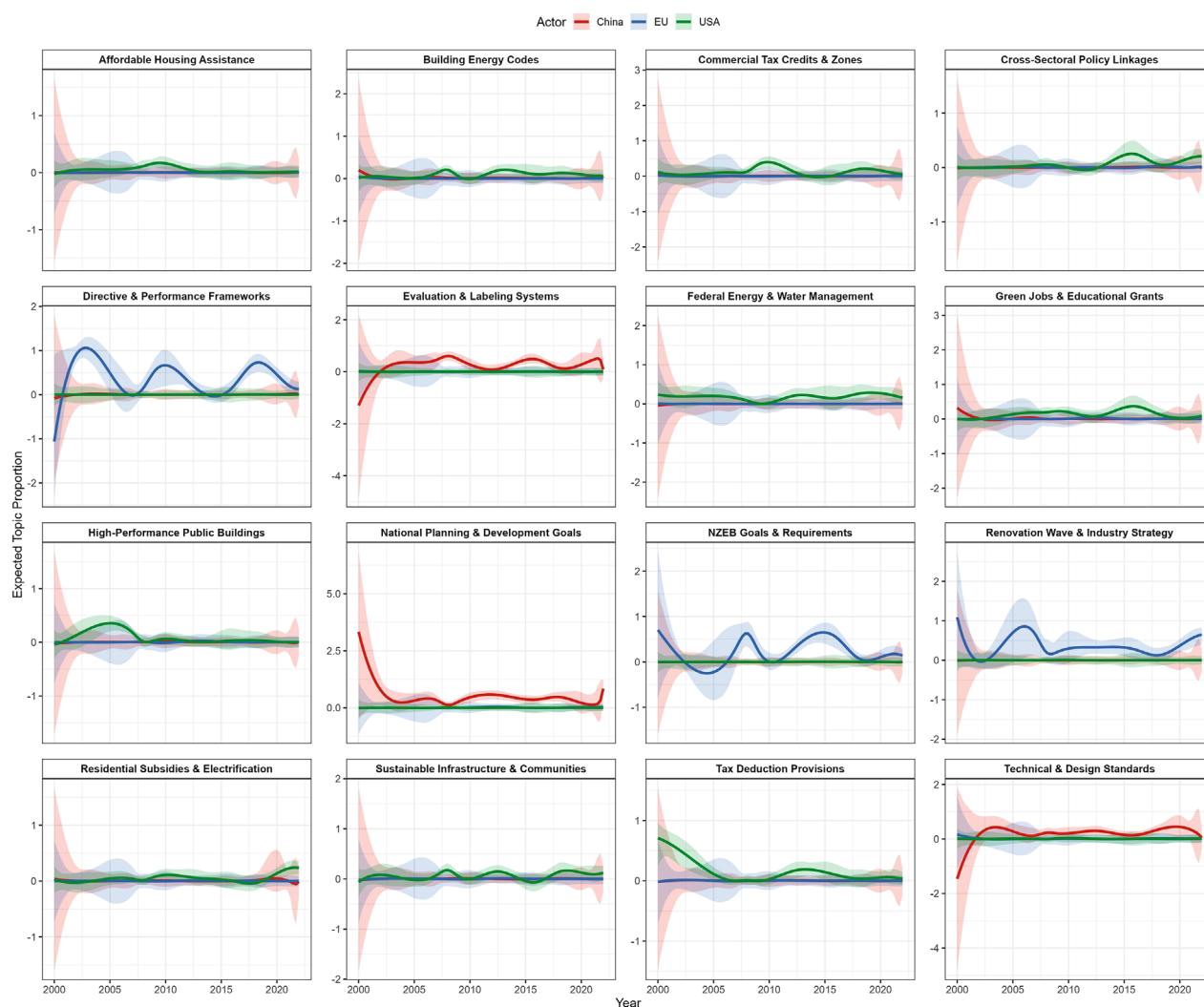


FIGURE 5

Estimated Effects of Covariates on Topic Prevalence: Temporal Trends by Actor. Note: The red, blue, and green solid lines represent the estimated trends for China, the EU, and the US, respectively. The shaded areas represent 95% confidence intervals. China: The peaks for Topic 13 (National Planning & Development Goals) align closely with the promulgation of the “11th Five-Year Plan” (c. 2006) and “12th Five-Year Plan” (c. 2011). EU: The three peaks for Topic 1 (Directive & Performance Frameworks) clearly correspond to the three key legislative milestones of the EPBD in 2002, 2010, and 2018. US: The early peak for Topic 15 (Tax Deduction Provisions) corresponds to the enactment of the Energy Policy Act of 2005, while the recent surge in Topic 9 (Residential Subsidies & Electrification) reflects new policy priorities.

direct fiscal incentives. The prevalence of Topic 15 (Tax Deduction Provisions) peaked in the early 2000s, during the period when a series of laws including the Energy Policy Act of 2005 were enacted, establishing tax incentives as a cornerstone of its policy toolkit. Topic 4 (Commercial Tax Credits & Zones) serves as a complement, continuously providing incentives for commercial real estate. Particularly noteworthy is Topic 9 (Residential Subsidies & Electrification), whose prevalence has surged in recent years, reflecting an increasing policy emphasis on direct subsidies for household energy retrofits and electrification.

On the other hand, another major feature of US policy is the use of the federal government’s own scale to set a market example. The long-term, stable, and high prevalence of Topic 3 (High-Performance Public Buildings) and Topic 8 (Federal Energy & Water Management) indicates that the federal government, through

legislation, imposes strict requirements on its own buildings (such as offices and schools) to meet higher energy and water conservation standards in procurement, construction, and operation. This approach does not directly regulate the market but rather indirectly guides technological development and encourages imitation by the private sector through the creation of a stable market demand for “green public procurement”. This dual-track strategy reflects both its tradition of respecting market forces and the unique way the federal government exercises leadership within the scope of its authority.

5.3.4 Emerging convergence: a shared toolbox amidst persistent governance philosophies

Although the core policy paths of China, the EU, and the US are shaped by their respective governance models and exhibit significant differences, the model also reveals an intriguing convergence in the

selection of specific policy instruments. The evolutionary trends of two themes, in particular, are crucial in this regard:

First is Topic 11 (Building Energy Codes). As a “push” instrument that sets market entry thresholds, its prevalence in the United States has shown a slow but steady increase, becoming a stable component of its policy framework. In the EU and China, this theme has also consistently maintained a foundational level of attention. This indicates that, regardless of the governance model, establishing and continuously updating baseline standards for building energy efficiency, with some degree of mandatory force, is recognized by all three actors as an indispensable policy cornerstone.

Second is Topic 9 (Residential Subsidies & Electrification). As a “pull” instrument designed to incentivize the energy-efficient retrofitting of existing building stock, its policy importance in the US has risen sharply in recent years, while it has also maintained stable attention in China and the EU. This reflects a shared challenge faced by all three actors: how to activate the vast and fragmented market for existing residential building renovations. In response, they have independently converged on the same solution: fiscal subsidies as the most direct policy tool.

This convergence at the level of specific instruments suggests that the world’s major economies are moving towards a “harmonious yet distinct” future. On the one hand, in confronting the common, physical challenge of decarbonizing the construction sector, they are becoming increasingly similar at the level of “what to do”—that is, in their choice of tools for their policy toolboxes. On the other hand, this instrumental convergence has not altered the deeply entrenched governance philosophies that dictate “how to do it”. The US will not adopt China’s five-year plans, and China will not establish an EU-style system of supranational directives. Understanding this complex picture, where “instrumental convergence” coexists with the “persistence of distinct governance philosophies”, is the key to grasping the future landscape of global green building governance.

6 Discussion

This chapter aims to move beyond the presentation of empirical results in Chapter 5, dedicating itself to a deep theoretical analysis of the phenomena revealed by the data. The core finding of this study is that although China, the EU, and the US are all committed to promoting the green transition of the construction industry, the policy paths they have chosen exhibit fundamental differences determined by their intrinsic governance models. This section integrates the data findings from Chapter 5 with the theoretical framework from Chapter 3 to systematically argue for and deconstruct these three distinct green building governance models, elucidating the deep-seated institutional logic behind their policy instrument choices.

6.1 Deconstructing the three green building governance models: from theory to evidence

The results of our data analysis provide robust empirical support for the theoretical framework proposed in Chapter 3. The three

unique policy paths we identified in the green building sector are highly consistent with the different innovation network models of China, the EU, and the US that scholars have observed in other frontier domains, such as global climate change mitigation (Ma et al., 2022). This indicates that macro-level governance structures and institutional traditions profoundly shape sector-specific tool selection and path dependence, with regulation and governance playing a pivotal role (El-Hakim and AbouZeid, 2024).

China’s “planning-driven model” is clearly substantiated by the data. The core of its policy framework is driven by a “troika” consisting of Topic 13 (National Planning & Development Goals), Topic 2 (Evaluation & Labeling Systems), and Topic 14 (Technical & Design Standards). As shown in Figure 5, the periodic, explosive growth of Topic 13 is perfectly synchronized with the promulgation cycles of the national “Five-Year Plans”, which eloquently demonstrates that top-down national planning is the supreme engine of China’s green building policy. Policy coordination between central and local governments further reinforces this model (Hu and Lin, 2022). The long-term, stable, and high prevalence of the two pillars for implementation—the nationally unified “Three-Star” evaluation system (Topic 2) and mandatory technical standards (Topic 14)—reveals the institutionalized pathway for translating macro-strategies into micro-level execution. This has been particularly effective in systematically promoting the advancement of green building technologies within the framework of the “Five-Year Plans” (Song et al., 2022). This model, characterized by “top-level planning initiating, mid-level standards supporting, and bottom-level projects executing”, is a direct reflection of its “state-led” and “experimentalism” governance traditions, whereby the state ensures the effective implementation of strategic goals through its formidable capacity for resource mobilization (for example, by involving large state-owned enterprises like the State Grid) (Zhang et al., 2023). The advantage of this “planning-driven model” lies in its strong state mobilization capacity and top-down execution, which can efficiently advance national strategic goals (like the “Five-Year Plans”), proving particularly effective in promoting the green transition of large public buildings and new urban districts. However, as the STM data suggests (e.g., the high prevalence of “Residential Subsidies” (Topic 9) in the US), China’s model may face challenges in mobilizing the existing, fragmented residential renovation market. Its limitations may also include a relative lack of flexibility or overlooking local heterogeneity during top-down implementation. This stands in sharp contrast to the US model, which is dominated by market incentives, and the EU model, which is based on a legal framework.

The EU’s “regulatory integration model” exhibits the characteristics of a supranational governance approach founded on law and guided by rules. The evolutionary trajectory of its policy agenda is entirely defined by the legislative cycle of Topic 1 (Directive & Performance Frameworks). The distinct peaks in Figure 5 correspond to the key revisions of the EPBD, highlighting the legislation-driven nature of its policies. Within this core legal framework, the EU is committed to advancing the implementation of policies in member states and improving the sustainability of the building stock (Ascione et al., 2022). It achieves this by setting uniform and forward-looking technical targets, such as those in Topic 5 (NZEB Goals), to coordinate and elevate the energy efficiency baseline across the entire internal market. This

dedication to establishing high-standard, legally binding, and uniform regulations is not merely for integrating its internal market but also serves as a core mechanism for exerting global influence and unilaterally exporting standards (Attia et al., 2023). As a recognized “leader” in global climate governance, the EU’s model aims to shape the global market through rule-setting (for instance, by pushing to achieve the 2050 building decarbonization goal) (Giordano and Andreotti, 2023), and its policy initiatives therefore carry global demonstrative significance.

The US’s “market-incentive model” manifests in the data as a hybrid strategy, shaped by market forces and constrained by federalism. The center of gravity of its policy toolbox is significantly skewed towards various fiscal instruments. The prevalence of Topic 15 (Tax Deduction Provisions), Topic 4 (Commercial Tax Credits), and Topic 9 (Residential Subsidies & Electrification) is far higher than in China or the EU. This is backed by a strong foundation in economic theory and empirical evidence suggesting that market-based incentives (such as fee reductions and tax credits) can effectively guide private-sector innovation and investment (Chen and Gou, 2023). However, a key to understanding the US model lies in its “federalism” structure. Because the authority to set mandatory building codes is largely reserved for state and local levels, the federal government faces complex political bargaining and institutional resistance when promoting uniform national standards, and federal-level setbacks have hindered the widespread adoption of green practices (El-Hakim and AbouZeid, 2024). Consequently, the federal level prefers to use its undisputed fiscal authority to provide guidance, while a distributed, polycentric adoption model has been formed, catalyzed by non-profit organizations and municipal policies (Brandtner, 2022). This polycentric, and at times fragmented, governance landscape is a direct reflection of its unique political traditions.

6.2 Different paths, common destination? convergence and divergence in global green building policy

The data from this study reveals a complex and profound picture: in the realm of global green building governance, China, the EU, and the US are advancing along three distinct paths determined by their institutional foundations. Yet, under the pressure of common challenges, their policy toolboxes are exhibiting increasingly clear signs of convergence. Understanding this dynamic, where “different paths” and a “common destination” coexist, is key to grasping the future trajectory of global environmental governance.

The divergence of paths is rooted in entrenched governance philosophies. As detailed in Section 6.1, the three models we identified in the green building sector are precise projections of the macro-governance paradigms of the three actors. China’s reliance on Topic 13 (National Planning & Development Goals) is an extension of its strong state capacity and “whole-of-nation system” into the environmental domain; the promotion of its low-carbon city pilot policies clearly demonstrates this top-down diffusion model (Luo et al., 2023). The EU’s dedication to Topic 1 (Directive & Performance Frameworks) is the core mechanism through which it, as a supranational entity, exerts global influence via rule-setting and market integration—a manifestation of the “Brussels Effect”

(Tumer and van Zeben, 2025). Meanwhile, the US’s preference for fiscal incentives, represented by Topic 15 (Tax Deduction Provisions), is the inevitable product of its federalist, polycentric governance landscape and its market-oriented traditions, in which local governments consequently play a pivotal role in policy innovation (Hazboun and Dixon, 2023; An et al., 2022). This path dependence in core governance logic makes it difficult for the three parties to converge on their starting points and macro-frameworks.

However, against this backdrop of path divergence, convergence at the instrumental level is occurring. The data clearly shows that Topic 11 (Building Energy Codes) and Topic 9 (Residential Subsidies & Electrification) are gradually becoming shared policy focuses for all three actors. This phenomenon can be reasonably explained by theories of policy learning and diffusion (Raghoo and Shah, 2022).

First, common economic and technological challenges form the basis for convergence. Faced with the common, concrete physical and economic challenges of decarbonizing the building sector, certain policy instruments gain cross-institutional appeal due to their proven effectiveness (Raghoo and Shah, 2022). For instance, “Building Energy Codes” (Topic 11), as “push” instruments that set a baseline for market entry, are a fundamental guarantee of energy efficiency in new constructions. “Residential Subsidies” (Topic 9), as “pull” instruments for activating the vast and fragmented market for retrofitting existing building stock, are the most direct means of overcoming initial investment barriers. This appeal is also being driven by economic and technological factors: for instance, as the cost-competitiveness and market maturity of energy-efficient technologies (e.g., heat pumps) increase, their economic viability makes “Residential Subsidies & Electrification” a common policy lever for all nations.

Second, policy learning and diffusion networks accelerate this process. When the design of specific policy instruments proves effective in addressing common problems, policy emulation, and even deeper policy transfer, can occur (Dome, 2024; Gregoire-Zawilski and Siddiki, 2025). This diffusion is increasingly facilitated by robust international policy networks, such as the global proliferation of voluntary standards like LEED and the “best practice” sharing platforms established by international organizations and academic networks.

Finally, common external pressures (environmental and economic) act as coercive drivers. In addition to active policy learning, common external pressures also accelerate this convergence process. Climate change, as a global crisis, constitutes the most powerful external driver, compelling nations to accelerate policy innovation and learning; the global trend of phasing out coal-fired power plants, for example, reflects this pressure (Vinichenko et al., 2023). Furthermore, deepening economic globalization creates implicit pressures for policy coordination. For instance, while the EU’s Carbon Border Adjustment Mechanism (CBAM) currently focuses on industrial goods, its logic could extend to building-related supply chains in the future. This would undoubtedly incentivize trade partners to align with EU standards on building material efficiency and embodied carbon, thus objectively promoting the convergence of related policies (Linsenmeier et al., 2023).

In summary, this study reveals a complex dynamic of “different paths leading to a common destination”. Due to their disparate domestic governance models, China, the EU, and the US have embarked on different policy paths. Yet, under the common pressure

of the global climate crisis, they are exhibiting increasingly clear convergence in their choice of key policy instruments, through mechanisms such as policy learning, innovation diffusion, and adaptation to external pressures. However, it must be emphasized that this instrumental convergence has not altered—and is unlikely to alter in the short term—their deeply entrenched governance philosophies. A “harmonious yet distinct” global green building governance landscape is taking shape: the specific “toolboxes” for achieving objectives are becoming more similar, but the macro-level “roadmaps” for deploying these tools remain decidedly distinct.

6.3 Constructing a data-driven analytical framework for green building policy

The core theoretical contribution of this study lies in the construction of a data-driven, dynamic, and comparative analytical framework for global green building policy, achieved through the systematic analysis of large-scale, long-term policy texts. This framework responds to the scholarly call for employing computational methods to analyze and construct government policy frameworks (de Jong et al., 2025). It moves beyond traditional qualitative descriptions and static comparisons to provide a new theoretical lens and empirical tool for understanding how macro-level governance structures shape sector-specific policy paths at a micro-level.

The core logic of this framework is built upon established theories in policy science, namely that the macro-level modes of governance of a political entity fundamentally determine its preferences for and the composition of its policy instrument mixes (Hurlimann et al., 2024). Our empirical findings clearly reveal the concrete manifestation of this “model-instrument” linkage in the green building domain. The framework is composed of two core elements: Four-Dimensional Policy Capacities and Three Governance Pathways.

First, the foundation of the framework is composed of the four macro policy dimensions that this study induced from the data. These dimensions are not merely clusters of the 16 specific themes but also represent four core “transformative capacities” essential for driving the green building transition (Hofstad et al., 2026): A. Strategic Frameworks & Directives (corresponding to ideational and institutional capacity); B. Planning, Standards & Evaluation (corresponding to planning and implementation capacity); C. Governance, Codes & Implementation (corresponding to regulatory and adaptive capacity); and D. Financial Instruments & Support (corresponding to market mobilization capacity). These four dimensions collectively constitute the policy space from which any actor can select when engaging in green building governance.

Second, the upper layer of the framework clearly delineates the three distinct yet well-defined governance pathways that China, the EU, and the US have carved out within this policy space. The differences among these three paths are not random but are the inevitable result of their intrinsic governance models and institutional logics. China’s “planning-driven” path is highly focused on Dimension B, systematically advancing the transition through powerful national planning, technical standards, and evaluation systems. The EU’s “regulatory integration” path is centered on Dimension A, integrating and leading the entire regional market

through legally binding supranational directives and forward-looking goals. The US’s “market-incentive” path primarily leverages Dimension D, supplemented by federal leadership-by-example from Dimension C, using a diverse array of fiscal tools to incentivize and guide a polycentric, market-led transition process.

Finally, this framework is a dynamic model that not only reveals divergent paths but also identifies “intersection points” of convergence. The three paths show clear points of convergence on key policy instruments such as Topic 11 (Building Energy Codes) and Topic 9 (Residential Subsidies & Electrification). This indicates that, despite vast differences in macro-level governance philosophies, policy learning and external pressures are compelling major global actors to move towards a shared toolbox when addressing specific technical and market challenges. What this framework reveals is not just a static combination of policy instruments, but rather the embodiment of “the politics of policy mixes” in sustainable transitions (Wang et al., 2023)—that is, how macro-institutions, political bargaining, and specific contextual pressures jointly shape the policy choices and evolutionary trajectories that we observe.

7 Conclusion

Against the critical backdrop of the global response to climate change and the push for a green transition in the construction industry, this study has conducted the first large-scale, dynamic, and quantitative comparative analysis of the macro-landscape of global green building governance. This was achieved by constructing a corpus of national-level policies from China, the EU, and the US spanning over 2 decades (2000–2024) and employing a cutting-edge computational method, the Structural Topic Model (STM). The research not only identified the 16 core themes that constitute the global policy agenda but, more importantly, revealed the complex dynamic of “different paths leading to a common destination” in global green building governance.

The core finding of this study is that China, the EU, and the US follow three distinctly different policy paths, each determined by their intrinsic governance models. China’s “planning-driven” model systematically drives industry transformation through national top-level design, exemplified by its “Five-Year Plans” and mandatory technical standards. The EU’s “regulatory integration” model is centered on legally binding supranational directives (such as the EPBD) and forward-looking technical goals (such as NZEB) to coordinate and lead its entire regional market. The US’s “market-incentive” model, operating within a federalist framework, focuses more on employing market-based tools like tax credits and fiscal subsidies, supplemented by the federal government’s leadership by example, to guide a polycentric, market-led transition process. However, despite this divergence in macro-level paths, the study also identifies increasingly significant points of policy convergence: on the two key policy instruments of “Building Energy Codes” and “Residential Subsidies & Electrification”, the three parties are moving towards a consensus.

The findings of this research have significant theoretical and practical implications. On a theoretical level, this study provides a robust, cross-national, empirical paradigm for the core proposition that “governance models determine policy instrument choice”, clearly demonstrating how macro-institutional structures shape

sector-specific policy frameworks at a micro-level. Furthermore, this research refines and constructs a data-driven, dynamic “Four-Dimensional Capacities, Three Pathways” analytical framework, offering a new theoretical lens for future comparative policy research. On a practical level, the findings provide policymakers with a valuable “policy mirror”, enabling them to optimize their national strategies by referencing the successes and failures of policy mixes under different governance models. At the same time, by identifying areas of policy convergence, this study points to the most promising directions for future international climate cooperation—namely, establishing global platforms for dialogue and best-practice sharing centered on the harmonization of building energy codes and incentive mechanisms for green residential retrofits.

Finally, this study has certain limitations, which in turn open up new avenues for future research. First, this study focused on national and supranational-level policies and did not delve into policy innovations at the sub-national level (e.g., state, province, city), even though these local practices are an indispensable part of the overall governance system, especially in the US. Second, as an analysis based on policy texts, this study reveals policy “intent” and “focus” but does not directly link them to actual “implementation outcomes”. Future research could utilize the policy theme framework constructed in this study as an independent variable, employing methods such as econometrics to test the actual impact of different policy mixes on performance indicators like carbon emission reductions and energy efficiency improvements in national building sectors. This would allow the field to make the leap from “policy analysis” to “policy evaluation”. For example, China’s “planning-driven” model may offer advantages in execution speed and scale, but it might face challenges regarding flexibility and local innovation incentives. The US’s “market-incentive” model can effectively stimulate market vitality and technological innovation, but it may be less efficient in achieving nationally consistent mandatory standards or addressing social equity. The EU’s “regulatory integration” model excels at setting high standards and leading global norms, but it may grapple with implementation gaps among member states and lengthy legislative cycles. These hypotheses, based on governance model divergences, provide concrete research directions for making the leap from “policy analysis” to “policy evaluation”.

Data availability statement

The datasets analyzed for this study can be found in the FigShare at <http://doi.org/10.6084/m9.figshare.30229000>.

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JC: Conceptualization, Data curation, Project administration, Writing – original draft, Writing – review and editing. YX: Data curation, Formal Analysis, Methodology, Writing – original draft. YY: Conceptualization, Supervision, Writing – review and editing. HH: Formal Analysis, Validation, Writing – review and editing. CW: Formal Analysis, Software, Validation, Visualization, Writing – original draft.

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Appendix A

