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Research Article

The Role of Language in Shaping Climate Futures: A Frame Analysis of Carbon Governance in China and the U.S.

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Abstract

Given the increasingly significant role of discursive frames in shaping climate change governance, this research addresses the following question: How does policy language, through the frames it employs, mediate the relationship between institutional intent and real-world carbon outcomes? To answer this question, the study proposes an integrated Language-Policy-Outcome (LPO) framework to compare carbon governance discourse in China and the United States (California) between 2007 and 2022. Combining quantitative methods (large-scale topic modeling and network analysis) with qualitative ecolinguistic frame analysis, it examines 209 official policy documents and links discursive dynamics to CO_2 emissions through correlation analysis. By bridging linguistic framing with empirical performance, this research advances a holistic understanding of how carbon governance discourse operates as an intermediary connecting institutional behavior, epistemic culture, and environmental outcomes. Results reveal that China's technocratic frame and California's

legalistic frame both operate largely within a weak sustainability paradigm, where short-term compliance and efficiency improvements are emphasized compared to systemic socio-ecological transformation. While both discursive systems exhibit strong linguistic and thematic coherence, their association with emission outcomes remains partial and context-dependent, suggesting that policy language acts as a mediating and conditioning factor rather than a direct causal driver in decarbonization. The analysis also identifies rebound patterns, where efficiency gains coincide with continued absolute emission growth, highlighting the complex interplay between discourse, economic dynamics and governance structures. Methodologically, the study demonstrates the value of a mixed-methods approach that combines computational scalability with interpretive depth and performance validation, contributing to a more integrative understanding of climate governance communication.

Keywords: Carbon governance; Ecolinguistics; Framing; Topic modeling (LDA); Policy discourse; Cross-correlation analysis

1. Introduction

Climate change governance increasingly depends not only on technological and institutional capacities, but also on discursive frames shaping how it is addressed and understood. Policy discourse can be defined as the whole of language, narratives and interpretative frameworks through which policy problems, solutions and responsibilities are constructed, contested and legitimized (Hajer 1995). Frames determine which challenges are perceived as urgent, who is held accountable and which interventions are regarded as feasible or desirable, making it a central mechanism in shaping collective climate action (Dryzek and Lo 2015). Consequently, divergent discursive frames often lead to distinct governance pathways, even under comparable environmental pressure. Examining these discursive mechanisms is, therefore, essential to understand why climate policies succeed or fail across different governmental systems.

Among the world's major emitters, China and the US represent two contrasting governance models and rhetorical traditions. China has adopted a centralized, state-led approach to decarbonization (Liu and Wang 2017) where targets as the "Dual Carbon Goals", pledging to peak carbon emissions by 2030 and carbon neutrality by 2060 (Li and Zhao 2025), are embedded in national planning, bureaucratic performance evaluation and industrial policy. In contrast, the US, exemplified by California, relies on subnational legal instruments and pluralistic decision-making, often mediated through legislative processes, market mechanisms and judicial oversight (Mazmanian Jurewitz and Nelson 2019; Fletcher 2009). Both systems have produced impressive climate agendas, yet none of the two has achieved a consistent trajectory toward deep decarbonization (Mastrandrea, Inman and Cullenward 2020; Liu et al. 2022; U.S. EIA 2024). This paradox raises a fundamental question: How does policy language, through the frames it employs, mediate the relationship between institutional intent and real-world carbon outcomes?

The research addresses this question by developing a computational-ecolinguistic framework to analyze and compare China and California carbon governance discourses from 2007 to 2022. Within this framework, large-scale topic modeling and network analysis are coupled with qualitative frame interpretation to uncover the structural logics underlying policy narratives. Unlike traditional frame analysis, which relies on small textual samples (Ali and Hassan 2022), this approach scales up to over 200 official policy documents and links discourse dynamics with actual carbon-emission performance. This integration allows the examination of whether changes in carbon governance policy discourse correspond to measurable shifts in CO_2 intensity and emission trends.

The scientific problem that motivates this study is twofold. First, existing research on climate communication has largely examined public media (see Hager, Alzafari and Rashid 2024; Schäfer and O'Neill 2017; Stöckl and Molnar 2017), leaving governmental policy discourse mostly

underexplored (Aziz and Ahmed 2024). Second, although numerous comparative studies examined differences between China and US in climate governance (see Lu et al. 2021; Young et al. 2015; Chai, 2023; Wu et al. 2022), relatively few address the discursive mechanisms that reproduce these differences and their environmental consequences. Moreover, the limited studies that do so tend to focus primarily on media discourse (see Huang and Liu 2025; Liu and Huang 2023; Chen and Liu 2025). By bridging linguistic framing and empirical performance, this research moves toward a comprehensive explanation of how discourse shapes policy behavior and environmental outcomes.

Our central argument is that carbon governance discourse operates as an intermediary mechanism linking institutional design, epistemic culture and environmental performance. In China, discourse operates through a technocratic-developmental frame: language constructs carbon mitigation as a component of industrial modernization and national rejuvenation, aligning ecological objectives with economic expansion (Heggelund and Nadin 2017). On the other hand, in California, discourse operates through a legal-institutional frame: language codifies climate responsibility within procedural and bureaucratic routines, emphasizing compliance and programmatic accountability (Al-Shboul 2023; Fletcher 2009). These two mechanisms differ in form but share a deeper functional logic: the institutionalization of control through expertise and state authority. Furthermore, they both promote incremental rather than transformative change, reflecting what ecological economists term weak sustainability, where environmental protection remains subordinate to growth rationales (Neumayer 2013).

By empirically tracing how these frames correlate with emission trajectories, this study contributes three interrelated insights. First, it demonstrates that discursive structures can be quantitatively mapped and linked to environmental indicators, offering a replicable method for evaluating policy versus outcome coherence. Second, it reveals that technocratic and legalistic frames, despite enhancing institutional coordination, reproduce rebound effects, in which efficiency improvements coincide with continued absolute emission growth. Third, it suggests that future climate governance, both in China and globally, must reframe the problem from “how to control carbon” to “how to reorganize socio-economic systems around ecological limits”. In this sense, discourse analysis is not merely descriptive but diagnostic, exposing linguistic and cognitive boundaries that constrain transformative actions.

The contribution of this paper is, therefore, conceptual, methodological and practical. Conceptually, it situates policy language as an intermediary (rather than deterministic) layer in climate governance, bridging political communication and sustainability science. Methodologically, it integrates computational natural language processing (LDA and network clustering) (Blei, Ng and Jordan 2003; Walter and Ophir 2019) with ecolinguistic interpretation (Stibbe 2021) and empirical

validation, forming a novel Language-Policy-Outcome (LPO) model. Practically, it informs policymakers on how narrative choices may reinforce or undermine decarbonization effectiveness, highlighting which discursive patterns may guide the design of more inclusive, reflexive and adaptive climate policies, enabling genuine sustainability transitions. This paper thus contributes to an emerging international dialogue on the role of language in shaping climate futures. By revealing how divergent policy systems converge in their reliance on managerial control and growth narratives, we argue that achieving net-zero goals requires not only technological and institutional innovation but also discursive transformation.

2. Methodology

2.1 Research Framework

This study constructs an integrated Language-Policy-Outcome analytical framework to investigate how policy language mediates the relationship between institutional intent and actual carbon emission performances. This framework conceptualizes policy texts as dynamic instruments, actively working to translate institutional logics into governance mechanisms and measurable outcomes. Discourse, therefore, operates both as a reflection and a shaper of policy action: it frames the legitimacy of state intervention, signals governance priorities and influence the behavioral responses of public and private actors.

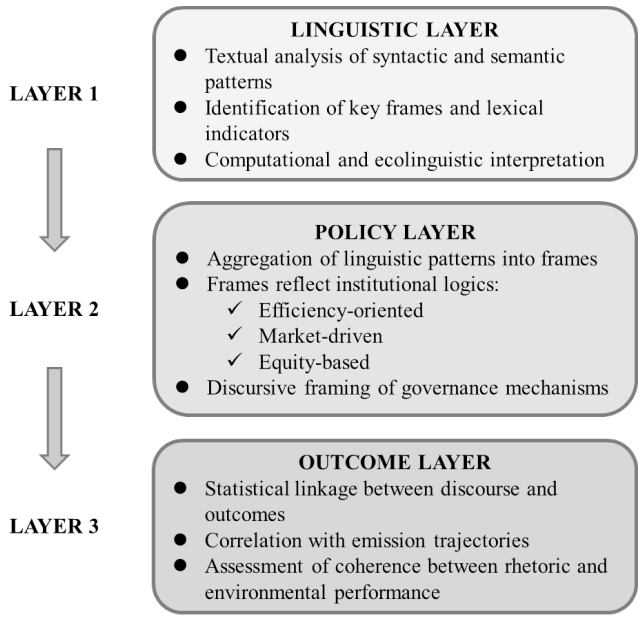


Fig. 1 LPO framework

The LPO framework consists of three interconnected layers (see Figure 1). The first, the linguistic layer, focuses on identifying syntactic and semantic patterns revealing carbon governance frames. The second, the policy layer, captures how these linguistic patterns aggregate into coherent frames embodying specific institutional logics, whether efficiency-oriented, market-driven or equity-

based. The third, the outcome layer, links discursive dynamics with emission trajectories to evaluate the degree of alignment between rhetorical commitments and environmental performance. By integrating computational linguistics, ecolinguistic interpretation and statistical analysis, the LPO framework allows the identification of the mechanisms through which discursive frames shape policy coherence and effectiveness, revealing how variations in policy language influence carbon governance outcomes.

2.2 Data and Sample

The empirical analysis draws on two corpora covering the period 2007-2022: the China CO_2 National Policies (CHCO2NP) and the California CO_2 State Policies (CACO2SP) corpora. The choice of time frame is deliberate: 2007 marks a milestone year for both China's and California's carbon emission governance, while extending the analysis through 2022 allows for the consideration of implementation lags, providing meaningful insights into the relationship between policy frames and actual CO_2 emission reductions. In China, 2007 saw the establishment of a national leading group, headed by the Premier of the State Council and including officials from 30 ministries, to address pressing climate challenges. In California, the Global Warming Solution Act, enacted on August 30, 2006, began its earliest implementation on January 1, 2007, when the California Air Resources Board (CARB) launched workshops to draft the AB32 (Paracha and Arens 2010).

The CHCO2NP corpus consists of 91 documents and 403,431 tokens (see Table 1) sourced from "China's low-carbon policy intensity dataset" (Dong et al. 2024). The database consists of documents from PKULaw, selected according to a keyword search based on the following words: *carbon reduction*, *greenhouse gases*, *energy conservation*, *energy efficiency*, *energy consumption* and *overcapacity*. Given the robustness of the method proposed by Dong et al. (2024) in compiling the corpus and the appropriate size of the database, this research includes all the documents from 2007 to 2022 flagged as national and does not make any addition.

The CACO2SP corpus consists of 118 documents and 55,377 tokens (see Table 1). Since no dataset collecting California's low-carbon policies is currently available, the original legislative documents were sourced from California Legislative Information Website[1]. In accordance with the keyword search employed by Dong et al. (2024), the "text search" function of California Legislative Information Website was employed to select policies including one or more of the following keywords: *carbon reduction*, *greenhouse gases*, *energy conservation*, *energy efficiency*, *energy consumption* and *overcapacity*. The policies resulting from the keyword text search were checked for

[1] California Legislative Information Website, (last access 2025/10/20), https://leginfo.legislature.ca.gov/faces/home.xhtml

consistency and coherence with the scope of the research and a total of 118 policies were included in the CACO2SP corpus. No document has been selected through the keyword *overcapacity*.

The size difference between the corpora does not compromise the reliability of the investigation since comparison was conducted in relative terms, assessing differences in magnitude rather than in absolute values. Moreover, when corpus size could potentially influence the results, appropriate scaling methods were applied to ensure robustness.

Table 1. Corpora description

Name of the corpus	Corpus Short Name	Administrative level	No. of Texts	No. of Tokens
China CO_2 National Policies	CHCO2NP	National level	91	403,431
California CO_2 State Policies	CACO2SP	State-level (California)	118	55,377

This dual-corpus design enables a cross-systemic comparison between two highly contrasting governance regimes: one centralized, developmental and state-driven, the other decentralized, regulatory and more participatory. By examining how each system articulates its carbon governance discourse, the analysis seeks to identify both convergent and divergent mechanisms through which policy language mediates institutional intent and implementation outcomes.

2.3 Analytical Procedure

To investigate China and US dominant frames and assess correlation with CO_2 emissions, this research employs a mixed-methods approach coupling NLP techniques with traditional ecolinguistic analysis. The methodology builds on Ma and Wang (2024), Walter and Ophir (2019) and Stibbe (2021) and involves six major steps that together operationalize the link between policy language and emission outcomes (see Figure 2). All procedures were implemented in Python 3.11.8.

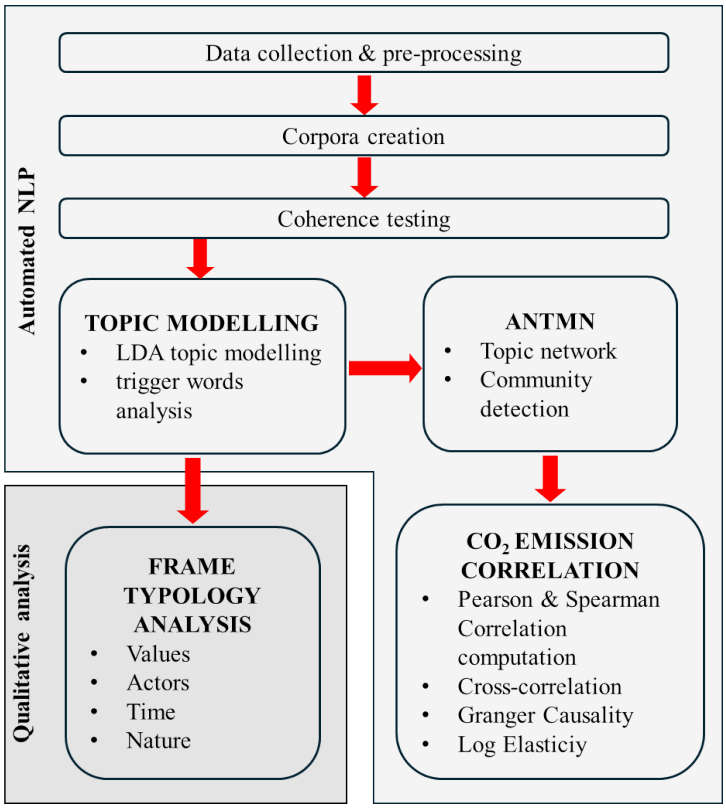
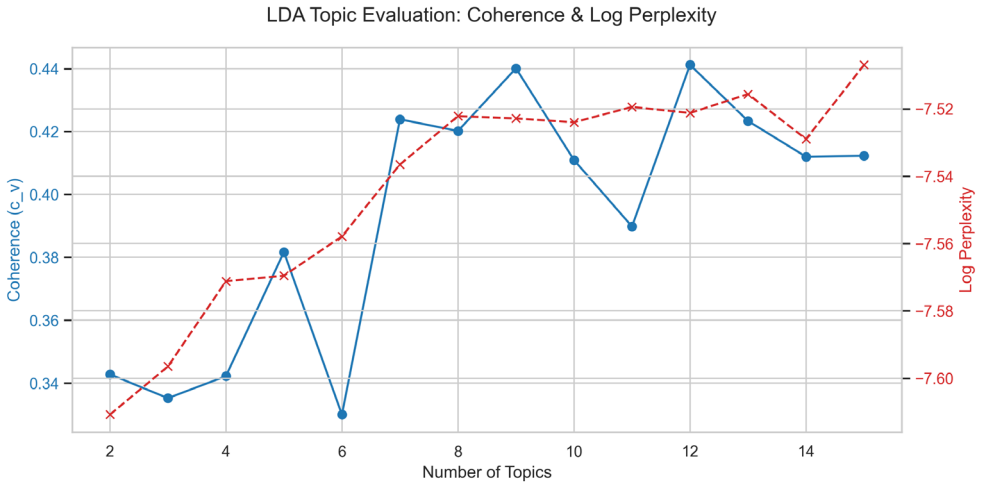


Fig. 2 Methodology framework diagram

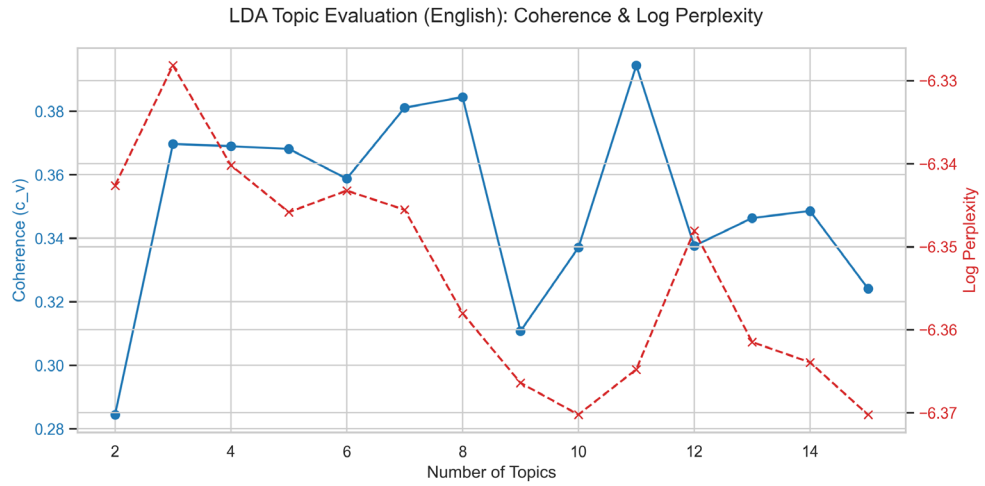
Step 1 involves text preprocessing and semantic validation. Metadata such as filename, document title, date and content were extracted. Texts were tokenized using "jieba" for Chinese and "nltk.word_tokenize" (based on the Peen Treebank tokenizer) for English. Stop-word lists, and custom dictionaries were used for further cleaning and word distribution optimization. After preprocessing, semantic inter-corpus coherence was assessed through Jaccard and Cosine similarity (see Supplementary materials). This check mitigated the risk that, despite using identical keywords, the retrieved documents addressed divergent contexts. Given limited tools for multilingual non-parallel corpus analysis, the CHCO2NP corpus was translated into English using a Python-based translation pipeline (Google Translate API in Python; see Fan et al. 2025 for a similar approach).

Step 2 is topic number identification through model perplexity and topic coherence. Topic modeling was performed using LDA. The optimal topic number was determined by evaluating topic perplexity and coherence across solutions from 2 to 15 topics. As shown in Figure 3a, for the CHCO2NP corpus coherence scores increased with the number of topics, peaking at 12 topics (coherence = 0.4412). In the CACO2SP corpus (Figure 3b), coherence peaked at 11 topics (coherence = 0.3944), indicating that this configuration offered the most interpretable set of topics. Log-perplexity consistently improved as topics increased, with the lowest value at 15 topics for both corpora (CHCO2NP = -7.5069; CACO2SP = -6.3702). Balancing interpretability (coherence) and

generalization (perplexity), a 12-topic model was selected for CHCO2NP and an 11-topic model for CACO2SP.



(a)



(b)

Fig. 3 Topic Perplexity and Coherence Score (a) CHCO2NP; (b) CACO2SP

Step 3 is frame identification through topic modelling and trigger words. LDA was implemented using the Gensim library and each topic's top keywords were reviewed to assign an interpretable label. After extracting topics, trigger words, salient lexical items, nominal or verbal, that draw from a particular domain to structure understanding in another (Stibbe 2021) were identified. Tables 2 and 3 summarize the topics and their labels for the Chinese and California corpora, respectively (see Supplementary materials for topics' list of topics with associated keywords). These results provided an initial mapping of the policy discourse in both jurisdictions.

LDA topic modeling revealed key thematic areas in China's and California's climate policy discourse. In the CHCO2NP corpus, 12 distinct topics (T0-T11) emerged (see Table 2 for topic labels).

For example, Topic 0 centers on technological development in heavy and strategic industries (e.g. rare earths, steel), underscoring the balance of industrial competitiveness with environmental protection; Topic 3 highlights renewable energy expansion and large-scale green infrastructure projects; Topic 5 focuses on reducing industrial overcapacity and restructuring inefficient enterprises; Topic 8 deals with developing carbon evaluation systems to hold localities accountable; Topic 10 emphasizes low-carbon industrial transformation and energy efficiency; and so on. Collectively, these topics portray a climate governance frame that is highly technocratic and developmental, integrating emissions mitigation into an agenda of industrial modernization and economic upgrade.

By contrast, the CACO2SP corpus produced 11 topics (US T0-T10; see Table 3) that reflect California's climate policy focus. Topic 0 outlines the regulatory governance of greenhouse gases, delineating the roles of state agencies and legal enforcement; Topic 2 targets GHG emissions in the electricity sector under compliance mandates; Topic 3 involves state support for emerging energy solutions like hydrogen (through funding and regulation); Topic 5 describes state-run financing programs for energy efficiency; Topic 7 relates to oversight of air-quality and transit programs; Topic 10 focuses on climate change mitigation via natural and working lands. These topics depict a discourse grounded in legalistic and institutional frames, where climate action is codified in statutes, funding mechanisms and bureaucratic oversight.

Table 2. Distribution of topics in CO_2 emission reduction policies (China, CHCO2NP corpus)

Topic Type	Label
Topic 0 (T0)	Strategic Resource Industries and Technological Advancement
Topic 1 (T1)	Industrial Upgrading and Technological Innovation
Topic 2 (T2)	Green Finance and Innovation-Driven Development
Topic 3 (T3)	Renewable Energy Development and Green Infrastructure
Topic 4 (T4)	Advanced Chemical Fibers and Sustainable Materials
Topic 5 (T5)	Overcapacity Reduction and Industrial Restructuring
Topic 6 (T6)	Textile and Silk Industry Modernization
Topic 7 (T7)	Corn Deep Processing and Feed Industry Development
Topic 8 (T8)	Carbon Emission Evaluation and Target Accountability
Topic 9 (T9)	Resource-Intensive Industries and Emission Control
Topic 10 (T10)	Green and Low-Carbon Industrial Transformation
Topic 11 (T11)	Energy Pricing Policies and Industrial Regulation

Table 3. Distribution of topics in CO_2 emission reduction policies (California, CACO2SP corpus)

Topic Type	Label
Topic 0 (T0)	Regulatory Governance of Greenhouse Gas Emissions

Topic 1 (T1)	Carbon Capture, Removal, and Geologic Sequestration
Topic 2 (T2)	Regulation of Greenhouse Gas Emissions in the Electricity Sector
Topic 3 (T3)	State Funding and Regulatory Support for Hydrogen Energy
Topic 4 (T4)	Statutory References and Language in Energy Regulation
Topic 5 (T5)	Energy Funding Programs and State Loan Mechanisms
Topic 6 (T6)	Science-Based Methane Assessment and Expert Consultation
Topic 7 (T7)	State Agency Oversight and Air Quality Transit Programs
Topic 8 (T8)	Public Building Energy Use and Conservation Programs
Topic 9 (T9)	State Energy Programs and Transportation Resource Management
Topic 10 (T10)	Climate Change Mitigation through Natural and Working Lands

After deriving topics, trigger word analysis confirmed these framing differences. In the Chinese corpus, frequently occurring nouns (e.g. *发展* "development," *技术* "technology," *产业/行业* "industry," *机制* "mechanism," *建设* "construction") and solution-oriented terms (*节能* "energy saving," *低碳* "low carbon") highlight development and technology. Common verbs include *提高* ("improve"), *创新* ("innovate"), *淘汰* ("eliminate"), *拟建* ("plan to build"), *评估* ("evaluate"), *执行* ("implement"), and *降低* ("reduce"). These lexical items invoke a **technocratic ecological modernization frame**, presenting climate mitigation as a technical challenge that can be managed through innovation, efficiency and industrial upgrading. The implicit assumption is that industry and technology are the primary agents of change: by improving processes, phasing out outdated capacity, and investing in new projects, economic growth and emissions reduction can progress side-by-side. This reflects a weak sustainability paradigm (Neumayer 2013) in which environmental goals are pursued without fundamentally altering economic priorities or lifestyles. In sum, Chinese policy language frames climate action as a techno-industrial enterprise closely tied to national development objectives (Zhang, Mol and Sonnenfeld 2007).

In the California corpus, trigger words activate a predominantly legalistic-bureaucratic frame. Notable nouns include *state, section, commission, code, agency, department, fund, moneys, loan, program, resources*. These terms emphasize governmental authority, legal codes, financial instruments and public programs, indicating that climate action is structured via legislation, regulation and state-managed funding. The discourse frequently references formal procedures (bills, code sections, agency responsibilities) and public institutional roles, underscoring a focus on compliance and administrative control. This legalistic framing is complemented by technocratic sub-themes, with words like *capture, sequestration, storage*, *geologic* appearing in contexts of carbon capture and storage programs. Therefore, California's policy discourse frames climate change as an issue to be managed through law, bureaucracy, and technology: what might be called a **legalistic ecological**

modernization approach. The government is the central actor, crafting rules and allocating resources to steer mitigation, which can inadvertently sideline community-level engagement or ethical debates about climate responsibility. Both the Chinese and Californian discourses, despite their different institutional flavors, rely on managerial control and expertise to tackle emissions, echoing weak sustainability in prioritizing near-term efficiency and compliance over transformative change.

In step 4, ANTMN was employed to identify relationships between topics and to build topic networks and communities. Each topic was treated as a node in a network, and edges between topics were weighted by their co-occurrence similarity in documents. Specifically, pairwise cosine similarity between topic distribution vectors (the LDA $\boldsymbol{\theta}$ matrix) was calculated to gauge the extent to which topics tend to appear together in the same documents. This approach draws on ANTMN techniques (Walter and Ophir 2019) to visualize discourse structure as a network of frames. The resulting topic networks (for each corpus) provide an "atlas" of the policy narrative's architecture: topics that cluster together indicate closely connected subframes or thematic alignments, whereas weakly connected topics signal more isolated or specialized concerns. Using this method, we built topic similarity networks for China and California and then applied community detection to identify modular groupings of topics. The Louvain algorithm (Blondel et al. 2008) was used to partition each network into communities of tightly interlinked topics. This yielded a small number of meta-frames or overarching frame groups in each corpus, offering insight into the internal coherence of each region's climate discourse. For instance, in China's network the topics formed a highly interconnected cluster centering on technological development (see Results, Figure 4), whereas in California's network the topics were somewhat more modular, reflecting distinct legal, administrative and technical sub-narratives (Figure 6 in Results). The network analysis thus adds a structural perspective, revealing whether the discourse operates as a unified narrative web or a set of disparate threads.

In step 5, automated results were complemented by a qualitative analysis based on Stibbe's (2021) framework for frame identification. Stibbe's indicators, partly derived from Blackmore and Holmes (2013), can be clustered into three main dimensions: (1) Value system – the values and ideologies a frame embodies (e.g.: economic growth, conservation, justice) and how these influence the reader's perception; (2) Actors – the agents to whom the frame assigns responsibility or agency (who is driving action, and who is the audience or beneficiary of the message); (3) Time – the temporal orientation of the frame, i.e. how it positions events across timescales (immediate vs. long-term focus, continuity vs. change over time); (4) Solution focus – whether the frame is primarily diagnostic (identifying and defining problems) or prognostic (proposing solutions and future actions). (Fletcher 2009). Using these questions as a guide, we qualitatively analyzed representative documents

and keywords for each LDA-derived topic. This interpretative step allowed us to refine the understanding of each frame: for example, confirming that China's technocratic frame consistently promotes modernization values and governmental actors, or that California's legalistic frame places public agencies at the center and leans heavily toward prognostic solution-oriented language. By triangulating in this way, we ensured the frames are contextually meaningful and not mere artifacts of the modeling process.

The final step 6 performs comparative and robustness analysis. In this step, we quantitatively linked the discursive patterns to actual CO_2 emission outcomes to evaluate alignment between talk and action. Annual CO_2 emissions data for China and California were obtained from the Our World in Data repository (Ritchie, Roser and Rosado 2024). For each corpus, we constructed time-series of topic intensity, a measure of the prominence of each identified frame over time (e.g. proportion of policy content devoted to a given topic per year). We then assessed the statistical relationship between frame intensity and emissions performance. This included calculating Pearson and Spearman correlation coefficients to test for linear and monotonic associations between the prevalence of certain frames and annual emission levels. To probe deeper, cross-correlation functions were used to check for lagged relationships (whether peaks in a frame's usage tended to lead or lag changes in emissions) and Granger causality tests were applied to explore directional influence over the 2007-2022 period. Additionally, an elasticity analysis was conducted to estimate how responsive emissions were to changes in discourse intensity (i.e. the percentage change in emissions associated with a percentage change in a frame's prevalence). This comparative analysis provided a quantitative check on the efficacy and sincerity of policy discourses: if a government's dominant frames strongly correlate with (or Granger-cause) emission reductions, it suggests the discourse may be driving real-world action; if not, it could indicate a disconnect where language serves more to legitimize policies than to drive change. Together, these six steps, from text cleaning and topic modeling to network mapping, qualitative interpretation and outcome correlation, form an integrated analytical procedure. This approach ensures that the identified frames are empirically grounded in textual data, interpreted through a critical ecolinguistic lens and evaluated against tangible environmental performance indicators.

2.4 Methodological Limitations

This study contributes to methodological innovation in three important ways. First, it integrates qualitative ecolinguistics with computational text analysis, offering a systematic framework for combining large-scale computational scalability and ecolinguistics' interpretative ambitions. In doing so, it demonstrates how large-scale policy language data can meaningfully capture ideological and

cognitive structures underpinning climate governance. Second, it introduces network modularity and topic interdependence as measurable indicators of policy narrative coherence, providing a structural lens to examine the degree of integration or fragmentation of carbon policy systems. Third, it couples discourse intensity with emission performance, establishing an empirical basis for assessing whether governance discourse aligns with its intended environmental outcomes. These contributions reposition ecolinguistics as a field capable of rigorously connecting discourse strategies to carbon performances, advancing an outcome-oriented approach that is at once critical, scalable, replicable and sensitive to temporal dynamics.

Nevertheless, certain limitations must be acknowledged. First, the LDA model's bag-of-words assumption overlooks grammar, syntax and word order, limiting its capability to capture nuanced semantic relations. Second, the translation of Chinese documents into English may introduce subtle semantic biases, as cross-linguistic equivalence is never fully guaranteed (van Dijk 2008). Third, while correlation and causality analyses reveal directional tendencies, they cannot establish definitive causal mechanisms between discourse and emission outcomes (Shadish, Cook and Campbell 2002; Granger 1988). Real-world emissions are driven by numerous external variables (e.g., economic growth, energy prices, industrial changes, political events) that may confound the relationship between language and outcomes. Thus, observed correlations must be interpreted with caution as they do not imply direct linguistic causation. To mitigate these limitations, the study employs methodological triangulation, robustness testing and integration of qualitative interpretation, ensuring that the analysis is empirically grounded and theoretically coherent.

3. Results

3.1 Topic networks and frame structures

Building on topic modeling results, this section explores how policy discourse operates as a system of interrelated relationships rather than as collection of isolated topics. By mapping co-occurrence patterns, ANTMN reveals relational structures shaping discourse internal coherence. Figures 4-7 display topic networks and their modular communities for CHCO2NP and CACO2SP corpora: nodes represent topics and edge weights indicate cosine similarity between topic distributions. Network density and modularity metrics serve as quantitative indicators of discourse coherence and fragmentation, providing the basis to assess the degree of institutional alignment, posited by LPO framework as the intermediate link between institutional intent and emission performance.

3.1.1 Network Coherence and discursive organization

CHCO2NP topic network (see Figure 4) reveals that China carbon emission discourse is structured as a tightly integrated system in which environmental problems are addressed through technological modernization, industrial upgrading and state-led governance mechanisms, reflecting a highly technocratic frame (Gilley 2012; Wang and Li 2021).

Document-topic distribution (**θ**) shows the predominance of three topics, T1, T9 and T10, accounting for 60% of corpus content. Secondary attention is directed to textile, silk and corn industries (T6, 9.3%; T4, 0.13%; T7, 0.3%), underscoring the continued salience of traditional industries within China's carbon discourse.

Topic similarity underscores network strong cohesive nature (density = 0.561), while simultaneously revealing key connections, including T9-T10 (0.131), T10-T1 (0.143), T9-T1 (0.131), T1-T7 (0.193), T9-T6 (0.073) and T4-T6 (0.283). These connections mirror distributional patterns, showing how sectoral modernization is embedded within a broader technocratic framework.

By contrast, topics such as T11 (3.0%), T2 (8.6%) and T3 (3.6%) remain peripheral and loosely connected, reflecting the marginal role of green infrastructure and green economy discourses. Particularly striking is the peripheral positioning of the renewable energy discourse, which contrasts with China's large-scale investments in renewable technologies, suggesting a gap between policy rhetoric and infrastructural priorities.

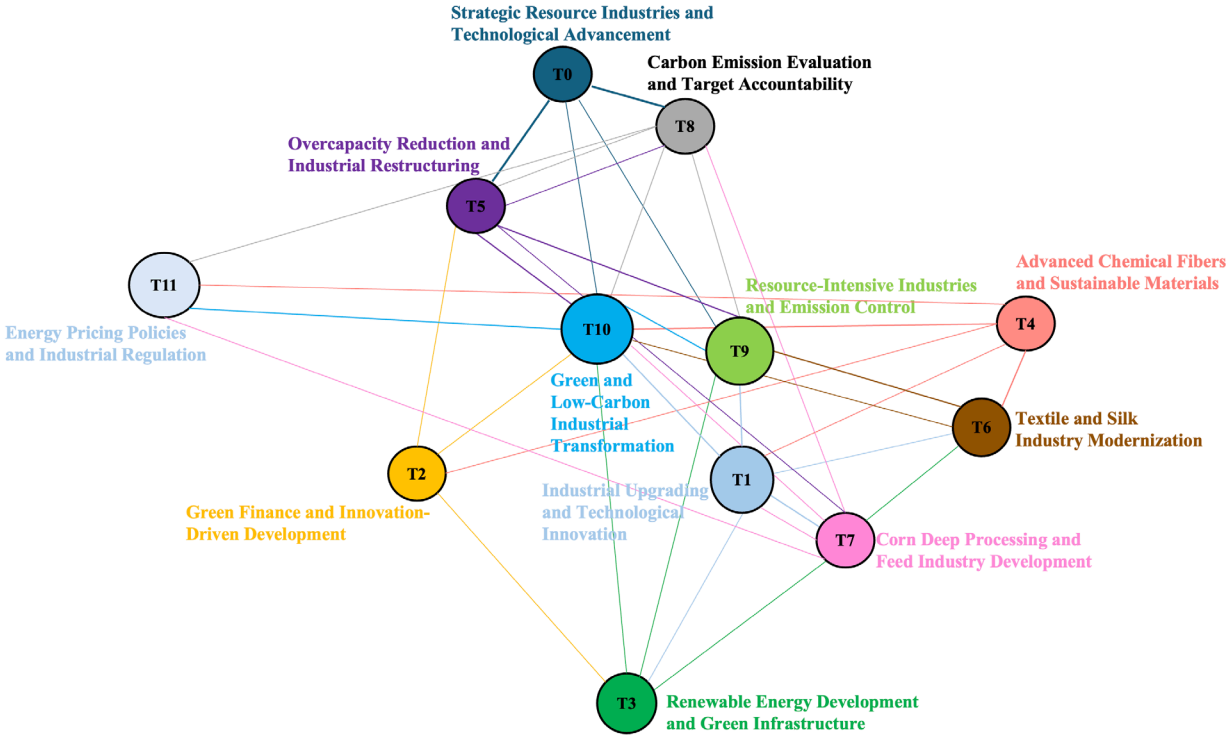


Fig. 4 Topic Network CHCO2NP

Community detection using Louvain algorithm reveals three thematic clusters, each representing a group of topics systematically co-occurring (see Figure 5).

The Governance and Low-Carbon Transition community (T0, T2, T3, T5, T8, T10, T11) emerges as the largest cluster, integrating both central (T10) and peripheral (T2, T3) topics into a narrative strand termed "green transition", where efficiency-driven industrial reforms and technological upgrading are coupled with renewable energy and green finance.

The Industrial Modernization and Emission Regulation community (T1, T7, T9) links industrial and agricultural modernization, underscoring agriculture's integration into China overarching development process.

The Sustainable Materials and Textile community (T4, T6), while occupying a peripheral niche, addresses modernization in textiles and chemical fibers, emphasizing efficiency and emissions reduction alongside the preservation of export competitiveness.

The relatively high density and low modularity (Q = 0.30) of the network indicate that communities are strongly interlinked, forming a cohesive narrative centered on technological development.

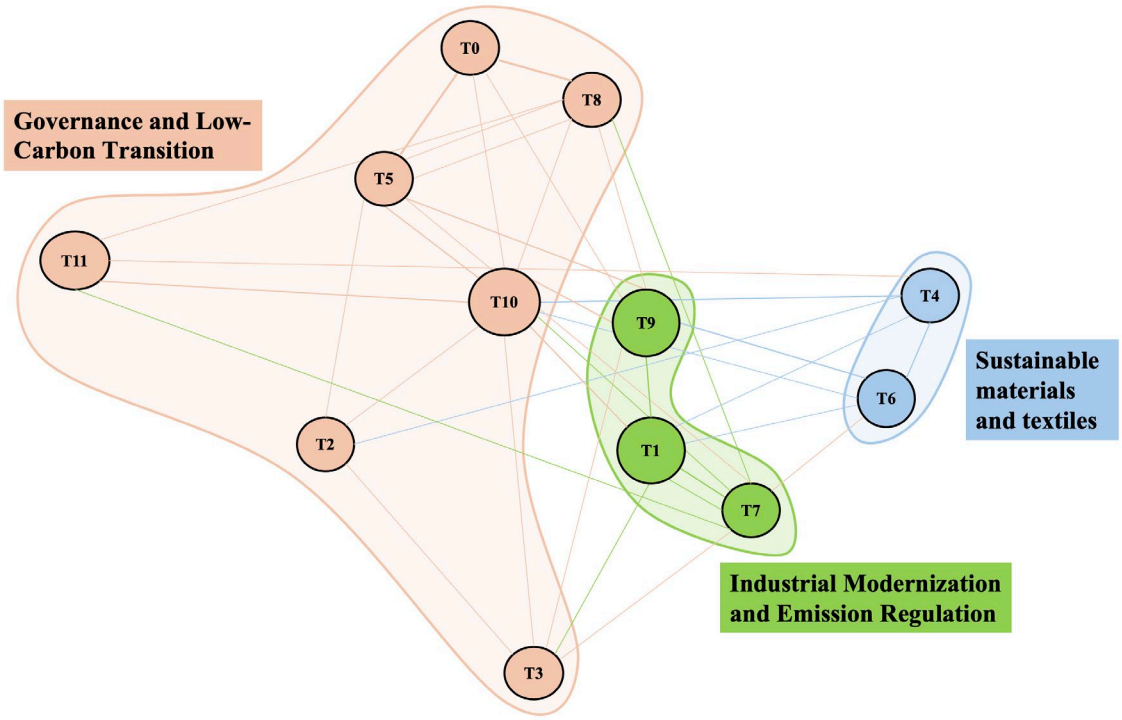


Fig. 5 Communities network CHCO2NP

CACO2SP topic network (see Figure 6) reveals that California carbon emission discourse is dominated by a legalistic frame where climate policy is articulated through codification, oversight and compliance, with technocratic elements embedded into statutory language.

Document-topic distribution (**θ**) reveals the predominance of three topics, T0 (30.6%), T5 (13.8%) and T9 (11.9%) while secondary attention is dedicated to established mitigation strategies,

as carbon reduction (T10 9.8%; T2 9.3%). By contrast, less mainstream mitigation options, as hydrogen-based energy (T3 7.2%; T6 2.4%), show limited distribution, indicating a lack of discursive authority.

Topic similarity reveals a highly connected structure (density = 0.691), indicative of a strongly homogeneous discourse. Strong connections between T4, an "empty" topic dominated by regulatory jargon, and other substantive topics (T4-T0 (0.545), T4-T5 (0.375), T2-T4 (0.313), T4-T9 (0.274), T4-T10 (0.215)), suggest that sectoral and technical solutions are discursively embedded in a legalistic framework, reinforcing government's centrality as the main stakeholder.

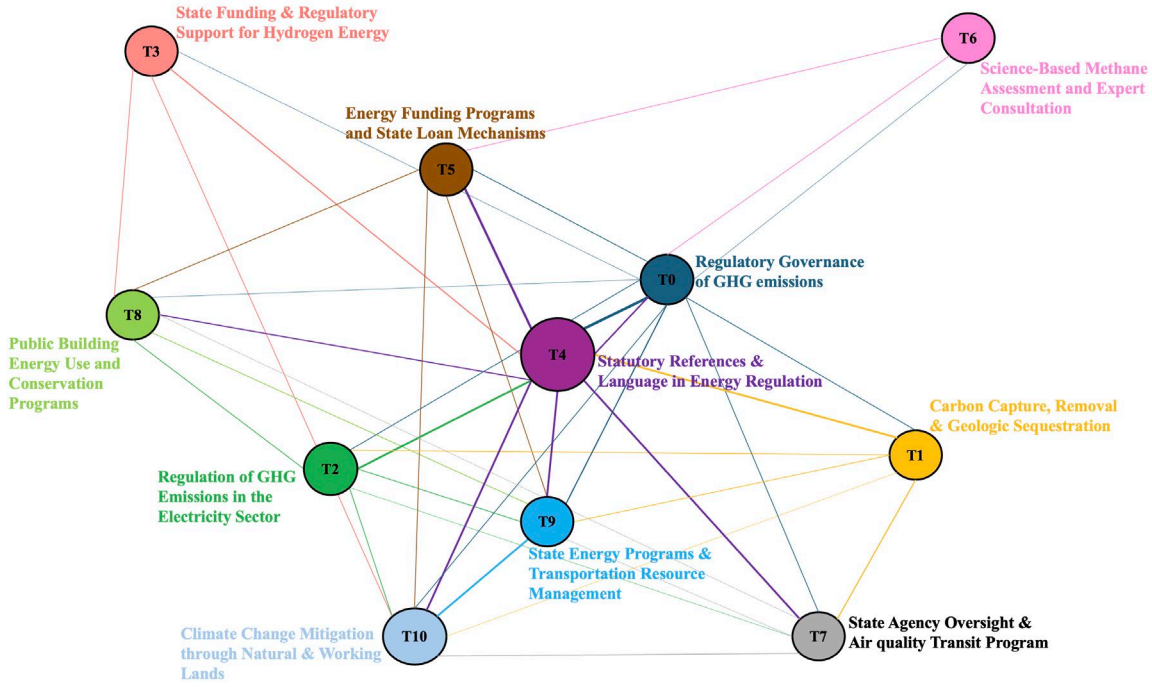


Fig. 6 Topic Network CACO2SP

CACO2SP corpus community detection reveals three thematic clusters (see Figure 7).

The Regulatory Governance and Programmatic Compliance community (T0, T2, T3, T4, T5, T6, T8) reflects a governance centered on systematic implementation and regulatory compliance, integrating new technologies into existing legal frameworks. This community integrates central topics (T5, T0) with peripheral ones (T8, T3, T6), by the means of T4, which acts as a magnet reinforcing overall communities' coherence.

The Carbon Capture and Oversight community (T1, T7) links a highly specialized technological theme (T1) with a governance-oriented topic (T7), reinforcing California's tendency to embed innovation within regulatory frameworks.

The Programs-Lands Integration community (T9, T10) reflects California's attempt to diversify mitigation strategies by linking sectoral programs with broader ecosystem-based approaches. The

presence of T9 underscores regulatory acknowledgment of land use and transportations as pivotal to CO_2 mitigation.

As shown by topic modelling, California carbon discourse is anchored in legal frameworks, administrative oversight and sectoral compliance. Low modularity (Q = 0.30) further shows a coherent narrative where specialized technical and ecological solutions are embedded into the broader regulatory system.

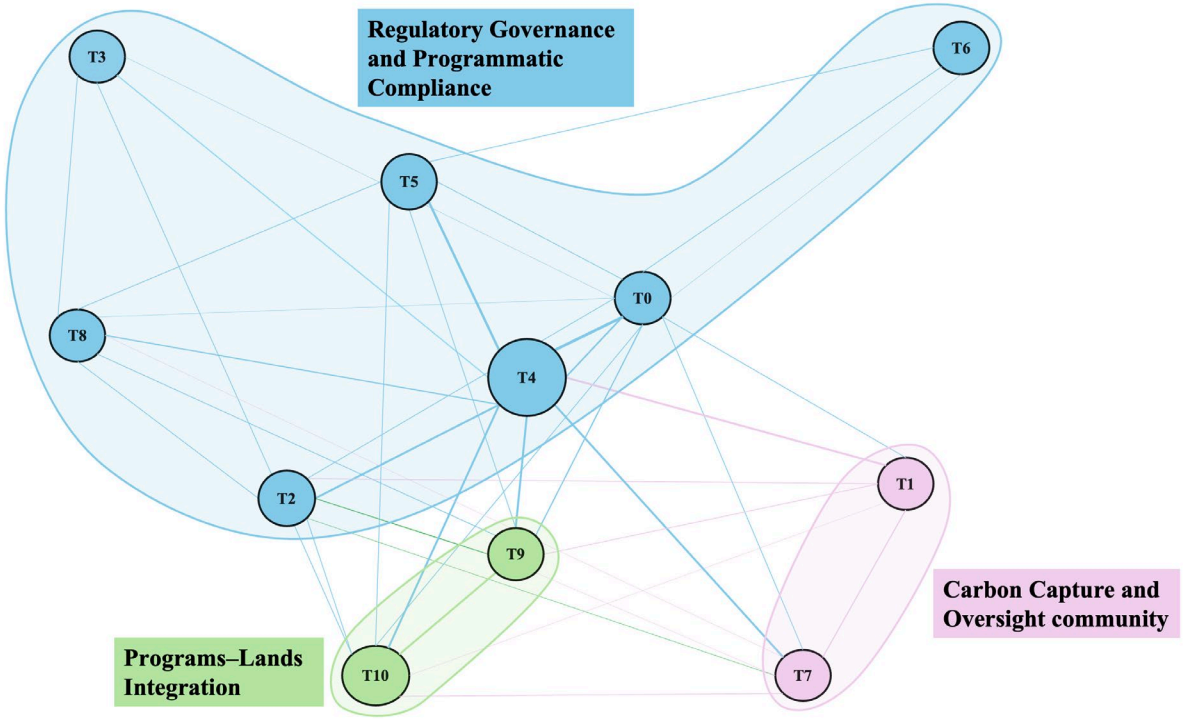


Fig. 7 Community network CACO2SP

3.1.2 Frame typology and structural interpretation

Quantitative frame analysis was concluded by a qualitative assessment employing Stibbe's framework (2021), addressing four indicators: 1) Value system; 2) Actors; 3) Time; 4) Solution focus.

The technocratic frame emerging from CHCO2NP corpus centers on efficiency, rationality and modernization, articulating sustainability as a form of "low-carbon modernization". By prioritizing structural and technological advancement, climate change is represented primarily as a technical and managerial challenge, leaving little space for broader social transformations. This approach conveys a narrative of coordinated progress rather than one of participatory transformation.

CHCO2NP discourse involves two main actors: enterprises and government. Enterprises are identified as key implementers of low-carbon strategies, responsible for upgrading technologies, reducing emissions and enhancing efficiency. The government, both central and local, acts as regulator and planner, drafting policies, establishing targets and assessing implementation. This dual-actor configuration reflects an expert-led oriented governance where authority and responsibility

are concentrated in enterprises, think-tanks and the state. The "erasure" of civil society resonates with what Stibbe's describes as "silencing of alternative stories we live by", which marginalizes collective and social voices in favor of dominant technocratic narratives.

Temporality unfolds across three leadership periods where Chinese carbon discourse maintains a technocratic frame despite changes in emphasis. The first period (2007-2013) was characterized by the implementation of the Scientific Outlook on Development, focusing on industrial upgrading and control of resource-intensive industry. The second phase (2014-2018) marked the consolidation of the Ecological Civilization concept, introducing green finance and low-carbon transformation. The third phase (2019-2022) emphasized the "Dual Carbon Goal", signaling stronger sustainability ambitions and integration of carbon targets into national planning.

Chinese technocratic frame is largely prognostic, constructing climate change as a technical and efficiency gap addressed through innovation. This solution-driven approach creates a dual narrative: a "story of progress", promising a better future through technological development and a "story of centralized progress", where solutions are imposed through a top-down model rather than emerging from a plurality of voices.

The legalist frame informing the CACO2SP corpus is centered on compliance, order and authority while still including efficiency and modernization. This frame activates a "story of centralized progress", where mitigation is a legal obligation and a "story of progress", where development is achieved almost exclusively through legal and bureaucratic efficiency.

Agency is attributed to the government, framed as the main stakeholder responsible for drafting new rules, implementing programs, ensuring compliance and fostering technological development, while general public and industrial sector, rather than as independent actors, are depicted as targets of regulation or beneficiaries of state-led programs. This pattern, as for the Chinese case, points to the "erasure" of civic agency, mirroring the absence of "stories of participation", crucial to democratic and ecological engagement (Stibbe 2021).

California's discourse shows a similar stability across policy cycles, where legal and bureaucratic frames dominate but adapt to changing federal contexts. Early implementation (2007-2008) focused on electricity-sector regulation; the following cycle (2009-2016) emphasized broader funding mechanisms and multi-sector engagement; subsequent periods (2017-2020) reinforced state-level autonomy during federal retrenchment, followed by renewed alignment and expansion of climate initiatives after 2020.

California legalistic frame is largely prognostic, prescribing solutions through statutory mandates, technical interventions and funding mechanisms. California's political environmental discourse operationalizes climate change as a legal and managerial challenge to be addressed through

state-led authority and short-term programs, confirming Fletcher's (2009) observation that policy frames often function more as "roadmaps for action" rather than as diagnoses of underlying causes.

3.1.3 Policy coherence as a mediating mechanism

Within the LPO framework, these findings substantiate the claim that policy coherence acts as the linguistic interface translating institutional intent into environmental performance. In China, coherence is achieved through top-down narratives, in which policy language orchestrates alignment across technological, administrative and economic domains, consolidating a unified modernization storyline. This approach fosters implementation efficiency but risks subsuming environmental goals under growth imperatives, by blurring the distinction between environmental and economic objectives. In California, coherence arises horizontally through procedural alignment and interagency coordination, enabling distributed governance but potentially weakening the capacity for large-scale systemic transformation.

The analytical significance of this section lies in converting abstract notions of "policy coordination" into quantifiable linguistic properties. Network density and modularity illustrate how governance systems think through language: the former capturing semantic concentration, the latter institutional differentiation. These discursive architectures are not mere reflections of governance style, but rather, they are active mechanisms conditioning how policies are formulated, communicated and implemented. As such, they represent the "missing middle" in climate governance analysis, the level at which institutional logics are reproduced and translated into administrative practice.

These results, further, reinforce the central argument: policy language is not a secondary by-product of governance but a causal mediator. Through its internal structure, policy discourse enacts institutional rationalities and delineates the boundaries of policy action. In China, a developmental rationality ties environmental reforms to modernization; in California, a legal rationality embeds it within procedural governance. Both structures illuminate how linguistic coherence simultaneously enables coordination and limits transformation, offering insights into the communicative foundations of carbon governance and the discourse patterns underpinning sustainability transition.

The stability of modular partitions confirms that observed patterns are intrinsic to policy discourse rather than artifacts of statistical noise. However, network analysis measures relational intensity rather than semantic depth; therefore, the next section couples these findings with emission data to examine whether discursive patterns correspond to measurable differences in carbon reduction outcomes.

3.2 CO_2 emission Correlation Analysis

To explore the link between discourse strategies and carbon reduction outcomes, topic distributions were analyzed against CO_2 intensity (tons per unit GDP). Correlation measures (Pearson and Spearman), cross-correlation lags, Granger causality and elasticity were computed for each topic across the 2007-2022 period, providing an interpretation of policy narratives in relation to real world effects, distinguishing proactive, reactive and restrictive framings, while highlighting trade-offs between emission reductions and economic productivity.

Correlation analysis shows that topics operate in distinct modes of governance, with varying temporal alignments and statistical associations with emissions. Tables 4 and 5 summarize the statistical associations for China and California, respectively.

Table 4. CHCO2NP Correlation analysis

Topic	Pearson CO_2	Spearman CO_2	Best Lag (yrs)	Pearson CO_2 intensity	Spearman CO_2 intensity	Elasticity β (CO_2)
Topic_0	0.057	-0.220	2	-0.080	0.201	0.003
Topic_1	-0.272	-0.367	-1	0.258	0.326	-0.008
Topic_2	0.238	0.453	3	-0.338	-0.472	0.019
Topic_3	0.204	-0.259	3	-0.241	0.233	0.001
Topic_4	0.343	0.107	-1	-0.291	-0.058	0.030
Topic_5	-0.137	-0.064	3	0.094	0.120	-0.002
Topic_6	0.072	-0.101	2	0.040	0.050	-0.002
Topic_7	-0.730	-0.771	2	0.746	0.739	-0.047
Topic_8	0.100	-0.117	-2	-0.152	0.076	0.006
Topic_9	-0.156	-0.432	3	0.197	0.525	-0.017
Topic_10	0.369	0.186	0	-0.258	-0.176	0.010
Topic_11	-0.272	-0.032	2	0.289	0.104	-0.005

In CHCO2NP corpus, correlation analysis detects four clusters: 1) Growth-Supporting; 2) Proactive but Growth-Linked; 3) Reactive; 4) Restrictive.

T10, T4 and T6 form the Growth-Supporting cluster. Moderate positive correlation with CO_2 emissions (T10 = 0.37, T4 = 0.34, T6 = 0.072) indicates that greater policy intensity coincides with rising emissions. While expected for T4 and T6, as sustainable materials do not necessarily optimize productive processes, T10 suggests the presence of a rebound effect: discursive promotion of low-carbon transition drives large-scale infrastructural investments improving efficiency but driving absolute emissions upward. Cross-correlation and elasticity analyses confirm this interpretation, showing a one-year lag for T4 and a contemporaneous effect for T10.

T2 and T3 belong to the Proactive but Growth-Linked cluster. Weak positive correlation (Pearson = 0.24 and 0.20) and long positive lags (+3 years), mirror China's five-year planning cycle.

Notably, T2 correlates with reduced CO_2 intensity (Pearson = -0.34; Spearman = -0.47), indicating efficiency gains. Yet, as with the Growth-Supporting cluster, efficiency gains are outpaced by expansion, producing a rebound effect where improvements in intensity coexist with overall emission growth. This cluster embodies the paradox of planned sustainability where policy language acknowledges ecological limits but remains bounded to growth imperatives.

T8 and T1 constitute the Reactive cluster. T8 shows a weak positive correlation (Pearson = 0.100) and a -2 lag, while T1 shows a moderate negative correlation (Pearson = -0.272) and a -1 lag. Correlations with CO_2 intensity are both positive (Spearman = 0.076/0.326), indicating that discourse gains prominence after environmental stress becomes visible. Indeed, T8 and T1 function as damage-control narratives, exemplifying reactive anthropocentric narratives in which environment enters political discourse only in response to disruptions to human systems.

T7, T9 and T11 belong to the Restrictive cluster. Negative correlation with CO_2 emissions (T7 = -0.73; T9 = -0.16; T1 1= -0.27) but positive with CO_2 intensity suggest restrictive or hard-stop measures, as shutdowns, rationing or slowdowns, which are effective in temporarily reducing emissions, but do not improve system's overall efficiency. Elasticity estimates for T7, T9, T11 (all small negative β) further confirm this pattern, underscoring the presence of crisis-driven mitigation dynamics.

Table 5. CACO2SP Correlation analysis

Topic	Pearson CO2	Spearman CO2	Best Lag (yrs)	Pearson CO2 intensity	Spearman CO2 intensity	Elasticity β (CO2)
Topic_0	-0.092	0.154	-3	-0.259	-0.359	-0.091
Topic_1	-0.094	-0.095	-3	0.095	-0.048	0.081
Topic_2	0.631	0.489	0	0.335	0.009	0.210
Topic_3	0.031	0.053	-2	-0.134	-0.125	-0.076
Topic_4			-3			
Topic_5	-0.106	-0.175	-3	0.021	-0.046	0.280
Topic_6	-0.040	-0.084	-3	-0.051	-0.028	
Topic_7	0.300	0.189	-2	0.156	-0.086	0.151
Topic_8	-0.005	-0.078	-2	0.316	0.102	0.182
Topic_9	-0.566	-0.339	0	-0.333	-0.254	0.049
Topic_10	-0.244	-0.221	-1	-0.312	-0.465	0.054

In CACO2SP corpus, correlation analysis identifies four clusters: 1) Reactive; 2) Mitigating; 3) Proactive; 4) Rhetorical.

T2, T7 and T8 belong to the Reactive cluster. T2 and T7 correlates positively with emission (Pearson T2 = 0.63; T7 = 0.30), while T8 is nearly neutral, yet all three correlate positive with CO_2

intensity (T2 = 0.34; T7 = 0.16; T8 = 0.32), indicating declining efficiency. In terms of temporality, T2 is contemporaneous (lag = 0), whereas T7 and T8 exhibit a -2 lag, suggesting that regulatory and oversight discourses emerge reactively, coinciding with rising emissions and declining efficiency despite regulatory framing.

T9, T10 and T5 form the Mitigating cluster. Topics correlate negatively with emissions (Pearson, T9 = -0.57; T10 = -0.24; T5 = -0.11), and show different temporal lags: T9 is simultaneous (lag = 0), T10 lags -1 and T5 lags -3. T9 and T10 correlate negatively with CO_2 intensity (Pearson T9 = -0.33; T10 = -0.31), whereas T5 correlates positively (Pearson = 0.02) with strong positive elasticity (β = 0.28), implying that financial programs risk reinforcing growth rather than mitigation. These results show that while land-use measures and transportation/energy programs are genuinely associated with emission reductions and efficiency gains, financial mechanisms risk undermining these gains by channeling resources back into growth-oriented pathways.

T3 and T6 constitute the Proactive cluster. Although correlations with total emissions are negligible (Pearson T3 = 0.03; T6 = -0.04), both topics correlate negatively with CO_2 intensity (Pearson T3 = -0.13; T6 = -0.05), suggesting modest but consistent efficiency gains. With a -3 lag, topics' intensity rises after a period of emission growth. T3 and T6 represent experimental and early-stage technologies, with limited immediate impact but forward-looking potential.

T0 and T1 form the Rhetorical cluster. Both show weak negative correlation with emission (Pearson T0 = -0.09; T1= -0.09), but they have divergent correlation with CO_2 intensity: T0 correlates negatively (Pearson = -0.26), while T1 correlates positively (Pearson = 0.09), suggesting that large-scale technological investments as carbon capture may impose additional energy costs without delivering system-wide gains. These topics function mostly as rhetorical responses, signaling regulatory attention rather than driving structural decarbonization.

4. Discussion

4.1 China: Technocratic Framing and Centralized Environmental Governance

China's climate governance discourse is dominated by a technocratic frame, emphasizing expertise, planning and administrative coordination in addressing environmental challenges. This orientation resonates with what Gilley (2012) describes in comparative literature as "authoritarian environmentalism", defined as a governance style where environmental policy is primarily designed and implemented through centralized administrative mechanisms. In this context, policy formulation and implementation are mainly driven by governmental actors, while public participation tends to occur within structured, state-coordinated channels (Kostka 2017).

This configuration, in which industrial and technological sectors operate in close alignment with national policy priorities, functioning as key vehicles for achieving low-carbon modernization, unveils a form of state-industry synergy, in which industrial actors are both policy implementers and innovation agents, supporting the alignment between environmental and economic goals.

While such an approach can be extremely effective in mobilizing resources, enforcing compliance and coordinating large-scale programs, its centralized nature may also underrepresent the role of social organizations and local communities in shaping environmental action, resulting in a governance strategy that is decisive and coherent, yet potentially constrained in terms of public inclusiveness and adaptive flexibility.

4.2 California: Legalistic Framing and State-Engineered Environmentalism

California's discourse is dominated by a legalistic frame in which the government is positioned as the principal stakeholder, responsible for compliance, technological development and supervision. This frame, while less authoritarian than the Chinese one, could be defined as state-engineered environmentalism, where bureaucratic agencies and industrial enterprises form decisive coalitions shaping policy trajectories. While this configuration provides strong regulatory capacity and facilitates technological innovation, it simultaneously sidelines community actors and grassroots initiatives, relegating them to peripheral roles. As a result, California's governance structure, despite its pluralistic and horizontal façade, ultimately reinforce hierarchical state-industry alliances, privileging technical expertise and institutional authority over civic participation and local knowledge. Nevertheless, compared with China, California accords greater prominence to NGOs, advocacy groups and subnational institutions, which retain a more substantive capacity to shape policy trajectories (Bäckstrand and Kuyper 2017). This suggests that while state-industry alignment remains a defining feature, participatory mechanisms and communicative feedback loops introduce a higher degree of diversification, mitigating centralization tendencies.

4.3 Ecolinguistic Perspectives on Climate Narratives

Chinese low-carbon discourse is structured around a transformation narrative that is closely aligned with national development priorities. This framing positions industrial upgrading and technological expansion as central strategies for achieving "low-carbon modernization", integrating ecological objectives with ongoing economic modernization goals. Such dynamics echo Stibbe's observation that climate change narratives often reflect existing economic and political logics, emphasizing continuity and stability within prevailing development models (Stibbe 2021). They also correspond to Neumayer's concept of weak sustainability, in which short-term measures relieve

immediate environmental pressure but may only partially engage with deeper systemic factors behind environmental degradation (Neumayer 2013). In ecolinguistic terms, China's discourse can be interpreted as a "story of adaptive survival", in which near-term emission reductions are prioritized to mitigate visible risks, while less emphasis is placed on longer-term regenerative transformation.

In the US, climate governance narratives differ in style but converge in substance with China's in their reliance on state-industry coalitions. The legalistic frame, reinforced by technocratic rationales, embodies a logic of weak sustainability: regulation delivers visible compliance and incremental efficiency gains, yet fails to drive long-term systemic change. In this framework, compliance functions as the primary indicator of governance success, while deeper socio-ecological inequalities, intergenerational risks and unsustainable consumption patterns remain obscured. This dynamic exemplifies Lakoff's (2010) argument that frames simultaneously highlight certain dimensions of reality while concealing others. As a result, by embedding environmental action within market logic and corporate partnerships, US climate discourse sustains growth-oriented priorities and aligns regulatory achievements with business competitiveness, ultimately reinforcing the very economic structures that generate ecological crises.

Both China and US discursive frames show a limited integration of transformative and regenerative visions: the discourse acknowledges ecological limits but subordinates them to development-first imperatives, narrowing down the scope of climate governance, reinforcing growth-oriented trajectories and contributing to familiar policy outcomes such as rebound effects, fragmented implementation and coordination gaps.

4.4 Discursive Coherence or Emission Fragmentation Paradox

The comparative analysis revealed a consistent pattern: policy language in both systems is linguistically and thematically coherent, but only partially aligned with ecological outcomes. This discrepancy points to a paradox in climate governance: highly coordinated and successful policy discourse can coexist with fragmented or inadequate emission results. In other words, having a coherent story about climate change is not the same as achieving effective climate action.

This paradox becomes clearer when we examine topic networks alongside emission outcomes. While the topic networks project a coherent and shared vision in each jurisdiction, emissions trends tell a more fragmented story. Emission trajectories are not dictated by government directives alone, but emerge from interactions among diverse actors and sectors, each pursuing distinct goals while navigating state regulations, structural inertia, rebound dynamics and systemic constraints (Haberl et al. 2020). Factors such as economic growth, energy market fluctuations, technological innovation and institutional design all shape outcomes alongside discourse, often overshadowing purely rhetorical

effects. In such a complex landscape, efficiency gains achieved through policy-driven transformations are quickly offset by scale effects (Jevons' paradox); reactive measures are introduced too late to significantly alter emission trajectories; and restrictive binding instruments, while efficient in the short term, often undermine efficiency in the long run, signaling forms of non-transformational control disguised as progress.

These dynamics underscore that discursive coherence does not automatically translate into material transformation. On the contrary, a well-orchestrated narrative can sometimes mask the persistence of non-transformational practices under the guise of strategic alignment. Importantly, the statistical correlation discussed in the results should not be read as evidence of direct causation but rather as indications of the causal tendencies embedded in the strategic use of language. Policy frames can constrain, enable and orient action, but they operate in a prescriptive and conditional manner rather than determining outcomes outright. Recognizing this highlights their value in exposing contradictions within policy formulation and implementation, while also underscoring the need for caution in making causal claims. Consequently, policy evaluation cannot rely on discourse analysis alone but must be complemented by an examination of broader socio-technical and economic contexts. For ecolinguistics, these findings underscore the need to extend its analytical scope to better account for material outcomes. An outcome-oriented ecolinguistics would critically assess whether discursive shifts translate into systemic ecological change. By bridging discourse with material indicators, the field can evolve into a transformative discipline capable of exposing discursive contradictions, uncovering hidden dynamics and contributing to the design of sustainability transition.

5. Conclusion

This study examined how carbon governance discourse in China and the US mediates the relationship between institutional design and ecological performance. The analysis revealed that, despite linguistic and thematic homogeneity, policy frames are only partially aligned with emission outcomes, exposing the strategic use of language in legitimizing policy narratives that promote growth-oriented paths by embedding them into decarbonization strategies.

The comparison highlights two distinct discursive paths: China advances a technocratic and development-driven frame, while California relies on a bureaucratic and legalistic one. While foregrounded by distinct frameworks, both fall within the paradigm of weak sustainability, where short-term compliance and efficiency gains are preferred to deeper socio-ecological transformations and state-industry alliances dominate the climate governance landscape. In this context, two clarifications are required: 1) the weak sustainability paradigm is primarily discursive, making it important to distinguish between "semantic" and "institutional" weak sustainability. In this study,

evidence points to semantic framing: discourse structures reproduce growth-oriented trajectories and constrain transformative options, but they do not themselves determine material outcomes, particularly in the absence of direct performance indicator analysis; 2) although both China and the US exhibit state-industry alliances, in the US, civil society, NGOs and subnational institutions retain a more substantive capacity to influence policies, even within this framework, whereas in China, opportunities for public engagement remain comparatively limited.

Methodologically, this study demonstrates the value of mixed-method approaches integrating computational techniques with qualitative interpretation and environmental performance validation. This approach provides a scalable framework for linking discursive narratives with ecological performance, offering a replicable methodology for future studies. Conceptually, it supports the development of an outcome-oriented ecolinguistics capable of tracing how language constrains and enables sustainability transition.

Future research should expand corpus size to cover a wider range of countries with diverse economic models, while also triangulating discourse analysis with complementary methods as stakeholder interviews, ethnographic observation or case studies. Such integrations would generate a more granular understanding of discourse-practice relationships, bridging the gap between policy narratives and ecological transformation. Furthermore, to strengthen the identification of a weak sustainability paradigm, symmetrical analyses incorporating institutional, economic and scientific data would provide a comprehensive basis for assessing whether weak sustainability remains confined to discursive patterns or also materializes within institutional arrangements. In particular, incorporating quantitative controls (e.g., GDP growth, energy prices) or running placebo comparisons could help isolate the specific influence of policy discourse amid broader macro-trends.

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Author contribution statement
Maria Stella Burgio: Conceptualization, Data Curation, Formal Analysis, Writing – original draft, Visualization, Writing – review and editing.
Gengyuan Liu: Conceptualization, Data Sources, Writing – review and editing, Validation, Supervision, Funding acquisition.
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Francesco Gonella: Writing – review and editing, Validation, Supervision, Funding acquisition.
All the authors have approved the final manuscript.

Data availability
Data used for this study are available upon request.

Declaration of competing interest

All the contributing authors report no conflicts of interest in this work.

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