



## Market Legitimacy of Carbon Trading: Evidence from Public Sentiment and Digital Discourse Analysis

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### Abstract

Carbon trading has gained prominence as a market-based instrument for climate change mitigation, yet its legitimacy depends heavily on public acceptance and trust. This study examines public sentiment, discourse structure, and narrative framing surrounding carbon trading in Indonesia using large-scale YouTube comment data. We applied BERT-based sentiment analysis, topic modeling, and narrative network analysis to a corpus of 15,000 user-generated comments, tracking discourse patterns and evaluating sentiment shifts before and after a major policy announcement. The findings reveal that negative sentiment dominates public discourse, though distinct neutral and positive clusters persist, indicating a polarized rather than uniformly oppositional public response. Narrative analysis shows that public discussions rarely engage with explicit policy or economic mechanisms; instead, carbon trading is embedded within broader social, national, and resource governance contexts. The narrative similarity network further identifies fragmented discourse communities rather than integrated public deliberation. Advanced metrics indicate moderate discourse concentration, a negative carbon market stability indicator, and a marginal policy communication effectiveness score. Event analysis demonstrates that policy announcements exert minimal short-term sentiment impact, with only a slight negative shift following the event. These results suggest that carbon trading policy legitimacy remains fragile in Indonesia's digital public sphere. We argue that effective communication strategies require sustained, context-sensitive engagement that translates technical mechanisms into narratives addressing local economic and social concerns, rather than relying solely on episodic or abstract climate framing. This study contributes an empirical socio-computational framework for monitoring real-time policy perception in emerging environmental markets.

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## INTRODUCTION

Carbon trading has emerged as one of the primary market-based instruments for addressing global climate change challenges. As nations strive to fulfill emission reduction targets under international environmental commitments, carbon markets increasingly function as strategic mechanisms for balancing economic growth with environmental sustainability. The expansion of carbon pricing mechanisms, including emissions trading systems and carbon offset markets, reflects a global transition toward market-driven environmental governance (Stavins, 2019). However, the effectiveness of carbon trading policies depends not only on regulatory design or market efficiency but also on public perception, acceptance, and trust toward the policy framework and its implementation (Schäfer, 2018).

The expansion of carbon market policies has coincided with the growing influence of digital media ecosystems on public discourse surrounding climate policy. Social media and online video platforms have fundamentally transformed how environmental policies are communicated, interpreted, and debated by the public. Among these platforms, YouTube occupies a particularly important position as a hybrid information space where policy explanations, expert opinions, market analysis, and public

reactions coexist (Yang et al., 2022). User-generated comments on YouTube provide rich narrative data that reflects public understanding, skepticism, policy trust, and perceived economic implications of carbon trading mechanisms. Consequently, analyzing digital discourse offers researchers an opportunity to capture real-time societal responses toward emerging environmental economic instruments (Pearce et al., 2018).

Despite the growing literature on carbon trading effectiveness, most existing studies concentrate on regulatory design, market performance, emission reduction outcomes, or corporate compliance behavior (Bayer & Aklin, 2020). While these approaches yield valuable macro-level insights, they frequently overlook the socio-discursive dimension of policy acceptance. Public communication research in environmental policy has traditionally relied on surveys or structured interviews, which may not fully capture spontaneous public narratives expressed in digital environments (Egan & Mullin, 2012). Consequently, researchers possess limited understanding of how carbon trading is framed, interpreted, and evaluated by the public in real-world communication spaces, particularly in developing countries where policy communication maturity and market familiarity vary considerably.

From a methodological perspective, recent advances in Natural Language Processing (NLP), particularly transformer-based models such as BERT, provide new opportunities for analyzing large-scale unstructured textual data with enhanced contextual accuracy (Devlin et al., 2019). NLP-based sentiment analysis, topic modeling, and narrative structure analysis enable researchers to move beyond simple opinion classification toward multidimensional discourse mapping (Liu, 2020). These techniques facilitate the identification of public sentiment trends, discourse concentration, narrative framing structures, and policy trust indicators from large-scale digital communication datasets. However, the application of advanced NLP methods to analyze public discourse on carbon trading remains relatively limited, especially using multimodal digital platforms such as YouTube, which combine informational content with participatory discussion (Rahman & Fitriyah, 2025).

In the Indonesian context, carbon market policy development remains in the early stages of institutional and public communication maturity (Ministry of Environment and Forestry, 2022). As the government continues developing regulatory frameworks and market infrastructure for carbon trading mechanisms, understanding public discourse becomes increasingly important. Public acceptance and trust constitute critical components for policy effectiveness, particularly for market-based environmental instruments that rely on behavioral adaptation, market participation, and long-term institutional credibility (Fairbrother, 2022). Without adequate public understanding and trust, carbon trading policies risk encountering resistance, misinformation, or low participation from key economic actors and society at large.

Therefore, this study aims to analyze public sentiment, discourse structure, narrative framing, and policy communication effectiveness related to carbon trading using large-scale YouTube comment data. By applying advanced NLP techniques, including BERT-based sentiment analysis, topic modeling, and narrative network analysis, this research seeks to construct an integrated public perception framework of carbon trading discourse. This study contributes to the literature by bridging environmental policy research, digital communication analysis, and computational social science approaches. Furthermore, the findings are expected to provide empirical insights for policymakers to design more effective communication strategies, improve policy transparency, and strengthen public trust toward carbon market mechanisms.

## **THEORETICAL POSITIONING**

This study is theoretically positioned at the intersection of environmental policy communication, digital public discourse, and computational social science. Specifically, this research integrates three main theoretical domains: environmental governance and market-based policy instruments, policy communication theory, and digital discourse analysis using computational methods. By combining these theoretical perspectives, this study aims to explain how carbon trading policies are socially constructed, interpreted, and evaluated within digital communication ecosystems.

From an environmental governance perspective, carbon trading is grounded in the theory of market-based environmental policy instruments (Montgomery, 1972). Market-based mechanisms, such as emissions trading systems, are designed to achieve environmental objectives through economic

incentives rather than direct regulatory enforcement (Tietenberg, 1990). According to environmental economic theory, the effectiveness of market-based environmental instruments depends not only on market efficiency but also on institutional credibility, regulatory trust, and stakeholder acceptance (Blackman & Harrington, 2000). In this context, public perception and policy legitimacy become critical factors influencing the long-term sustainability of carbon market mechanisms. Therefore, analyzing public discourse surrounding carbon trading is essential to understanding the broader socio-institutional environment supporting policy implementation (Gunningham & Sinclair, 2002).

From a policy communication perspective, this study draws on policy communication and public policy acceptance theories, which emphasize that policy effectiveness is strongly influenced by how policies are communicated, interpreted, and socially negotiated (Lasswell, 1948). Modern policy communication theory highlights that public understanding is shaped not only by formal government communication but also by decentralized communication channels, including digital media platforms (Cairney, 2016). The shift from one-way policy dissemination toward interactive and participatory communication environments has created new challenges for policymakers (Nisbet, 2014). Public narratives, sentiment expressions, and interpretive frames formed in digital spaces can significantly influence policy legitimacy, compliance behavior, and trust toward regulatory institutions (Bäckstrand & Lövbrand, 2019).

From a digital discourse and computational social science perspective, this study is grounded in the concept that large-scale digital text data represents observable manifestations of collective social cognition (DiMaggio et al., 2013). Online discourse can be analyzed to reveal underlying social perceptions, narrative structures, and ideological framing related to policy issues (Berger & Luckmann, 1966). Advances in Natural Language Processing, particularly transformer-based language models, enable researchers to analyze digital discourse with contextual sensitivity and semantic depth (Vaswani et al., 2017). In this study, NLP techniques are used not only to measure sentiment polarity but also to identify discourse structures, narrative framing patterns, and network-based relationships between public narratives related to carbon trading (Mohammad & Turney, 2013).

Conceptually, this study adopts a socio-computational policy perception framework, which assumes that public sentiment, discourse structure, and narrative framing collectively shape policy acceptance and trust formation (Mutz, 2011). Public sentiment reflects evaluative attitudes toward carbon trading, while discourse structure captures dominant topics and issue salience within public communication. Narrative framing represents how carbon trading is interpreted through economic, environmental, or regulatory lenses (Goffman, 1974). These three dimensions interact to form an integrated representation of public policy perception in digital environments (Chong & Druckman, 2007).

The theoretical novelty of this study lies in integrating environmental policy theory with computational discourse analytics. While prior studies often examine carbon trading effectiveness through economic performance or regulatory compliance metrics, this study introduces a discourse-driven policy perception model using large-scale digital communication data. Furthermore, by incorporating narrative network analysis and dynamic topic evolution analysis, this study extends traditional policy communication research toward real-time digital policy perception monitoring (Wasserman & Faust, 1994).

Thus, this research contributes theoretically by expanding the understanding of carbon market governance beyond institutional and economic analysis toward socio-digital perception analysis. In addition, this study provides a conceptual bridge between environmental policy research and computational social science by demonstrating how digital discourse analytics can be used as an empirical tool to evaluate policy communication effectiveness and public acceptance dynamics in emerging environmental markets.

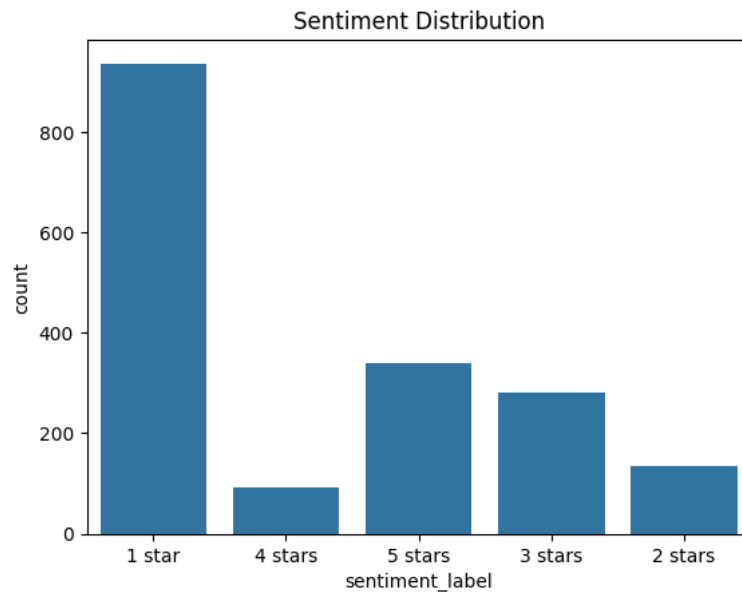
## **RESULTS AND DISCUSSION**

### **A. Result**

#### **1. Sentiment Analysis**

The sentiment distribution analysis reveals that public perception of carbon trading is predominantly characterized by strongly negative sentiment, as reflected in the 1-star sentiment category. This category demonstrates the highest frequency compared to other sentiment categories,

suggesting that a substantial proportion of public comments express negative evaluations toward carbon trading.



**Figure 1.** Sentiment Distribution

In addition to the dominance of negative sentiment, the distribution also reveals a relatively substantial presence of positive sentiment, particularly within the 5-star sentiment category. This finding indicates that despite the prevalence of negative evaluations, a segment of the public expresses highly positive perceptions of carbon trading. Meanwhile, the neutral sentiment category (3-star sentiment) also demonstrates a relatively high frequency, suggesting that a portion of public discourse remains informational or moderately evaluative in nature.

Moderately negative sentiment (2-star sentiment) and moderately positive sentiment (4-star sentiment) appear in smaller proportions compared to the extreme sentiment categories. This distribution pattern suggests that public discourse tends to concentrate around stronger evaluative positions rather than moderate opinions, consistent with findings from previous studies on climate policy discourse (Cody et al., 2015).

## **2. Narrative Frame Distribution in Carbon Trading Discourse**

The narrative frame distribution analysis shows that the majority of public discourse related to carbon trading is categorized under the other frame. This category represents a substantially higher frequency compared to all other identified narrative frames, indicating that a large portion of public comments does not explicitly align with the predefined climate, policy, or economic narrative categories.

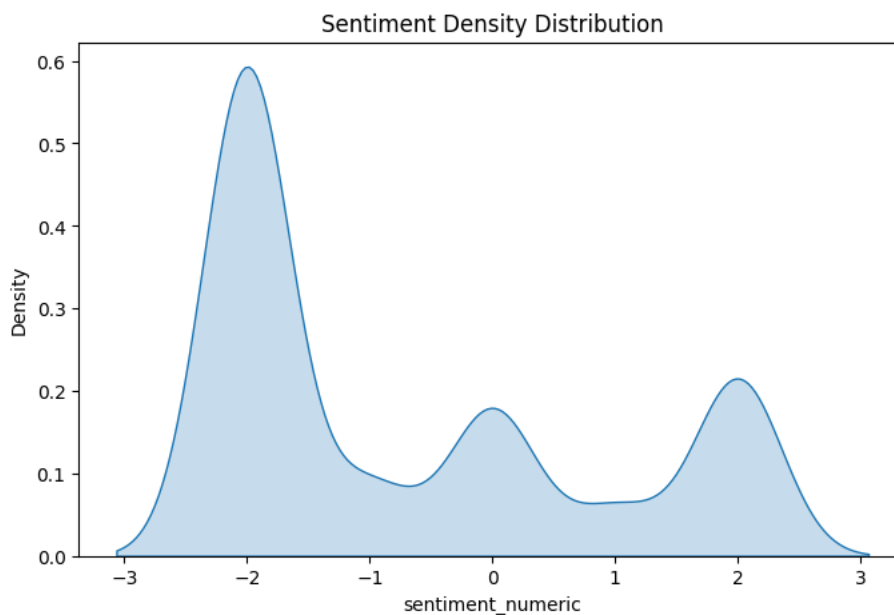


Several environmental-related keywords such as carbon, emissions, lingkungan (environment), and lahan (land) appear with relatively high frequency, suggesting that public discourse is partially centered on environmental issues and natural resource management. Additionally, geographical references such as Indonesia, Kalimantan, and negara indicate that public discussions frequently connect carbon trading to national development, regional environmental conditions, and resource governance. This pattern is consistent with research by Kaiser et al. (2021), who found that climate policy discourse in developing countries often emphasizes national sovereignty and resource management.

The word cloud also highlights the presence of general social discourse terms such as masyarakat, orang, manusia, and conversational terms such as aja, kalo, and gak, which reflect informal public communication patterns typical of social media discourse. The presence of these conversational expressions indicates that discussions surrounding carbon trading occur within broader social conversation contexts rather than purely technical or policy-focused discussions, echoing findings from Rahman and Fitriyah (2025) regarding the informalization of environmental policy discourse online.

#### 4. Sentiment Density Distribution of Carbon Trading Discourse

The sentiment density distribution illustrates the overall spread and concentration of sentiment scores related to carbon trading discourse. The distribution shows a dominant density peak located in the strongly negative sentiment range, approximately around the lower bound of the sentiment scale. This indicates that a large proportion of public discourse is concentrated within strongly negative sentiment values.



**Figure 4.** Sentiment Density Distribution

In addition to the dominant negative peak, the distribution also reveals secondary density peaks in the neutral sentiment range and the strongly positive sentiment range. The neutral sentiment peak indicates the presence of public discourse that reflects informational, descriptive, or non-evaluative expressions toward carbon trading. Meanwhile, the positive sentiment peak indicates that a segment of public discourse expresses favorable evaluations toward carbon trading, consistent with findings from Bucur et al. (2024) on divided public opinion regarding carbon pricing mechanisms.

The density curve demonstrates a multimodal distribution pattern, characterized by multiple sentiment concentration points rather than a single dominant central tendency. This pattern indicates that public sentiment toward carbon trading is distributed across multiple evaluative clusters, including strongly negative, neutral, and strongly positive sentiment groups. This multimodal distribution aligns with research by Druckman and McGrath (2019), who documented polarized public responses to climate policy interventions.

## 5. Advanced Discourse and Sentiment Stability Metrics

The advanced discourse and sentiment stability metrics provide an aggregated quantitative representation of public discourse characteristics related to carbon trading, as presented in Table 1. The Sentiment Polarization Index is recorded at 1.584, indicating a relatively high dispersion of sentiment values across the sentiment spectrum. This value suggests that public discourse reflects a wide distribution of evaluative opinions, with sentiment expressions distributed across strongly negative, neutral, and strongly positive ranges rather than being concentrated around a single dominant sentiment tendency. This level of polarization is comparable to findings from studies on other contentious environmental policies (Marozzi, 2015).

**Table 1.** Advanced Carbon Trading Discourse and Sentiment Metrics

<b>Metric</b>	<b>Value</b>
Sentiment Polarization Index	1.584
Discourse Concentration Index:	0.163
Carbon Market Stability Indicator	-0.439
Policy Communication Effectiveness	-0.017

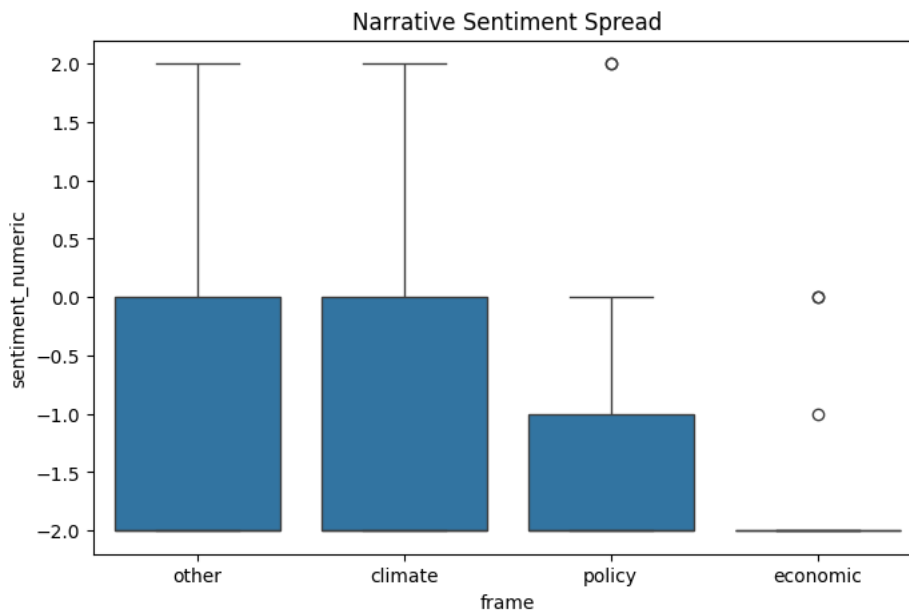
The Discourse Concentration Index is measured at 0.163, indicating a moderate level of discourse concentration across topics or narrative themes. This value suggests that public discourse related to carbon trading is distributed across multiple thematic structures rather than being dominated by a single discourse narrative. The index value reflects a relatively diversified discourse structure within the observed digital communication dataset, consistent with research by Maier et al. (2020) on the fragmentation of online policy discourse.

The Carbon Market Stability Indicator is calculated at -0.439, indicating an overall negative stability tendency within the sentiment structure of carbon trading discourse. This value reflects the interaction between average sentiment tendency and sentiment dispersion across the dataset, suggesting that overall sentiment conditions lean toward negative evaluations when accounting for sentiment variability. This finding aligns with research by Fairbrother (2016) on public skepticism toward market-based environmental policies in developing economies.

The Policy Communication Effectiveness Score is recorded at -0.017, indicating a slightly negative value that is positioned close to the neutral boundary. This value suggests that policy-related discourse sentiment is marginally weighted toward negative sentiment while remaining relatively close to neutral distribution levels. The relatively small magnitude of this value indicates that policy-related discourse does not demonstrate strong directional dominance toward either positive or negative sentiment clusters, echoing findings from Tunca (2026) regarding the conditional nature of policy acceptance.

## 6. Narrative Sentiment Structure

The narrative sentiment structure analysis illustrates the distribution and variability of sentiment scores across different narrative frames in carbon trading discourse. As shown in Figure 5, sentiment distributions vary across narrative categories, including other, climate, policy, and economic frames.



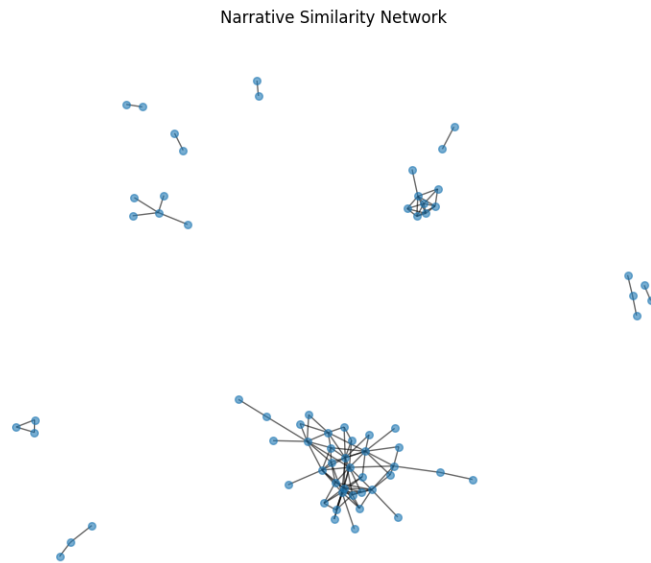
**Figure 5.** Sentiment Distribution by Narrative Frame

The other narrative frame demonstrates a wide sentiment range, spanning from strongly negative sentiment values to strongly positive sentiment values. This distribution indicates that discourse classified within the other category contains highly diverse evaluative expressions, reflecting heterogeneous public responses that are not concentrated around a single sentiment tendency. This heterogeneity suggests that public discourse which does not fit neatly into predefined policy categories often contains the most varied evaluative perspectives (Bennett & Segerberg, 2013).

Similarly, the climate narrative frame also exhibits a broad sentiment distribution across the sentiment scale. The presence of both strongly negative and strongly positive sentiment values indicates that climate-related discussions associated with carbon trading generate varied evaluative responses within public discourse. This pattern is consistent with research by Gómez-Casillas and Márquez (2023), who found that climate discourse on social media exhibits significant affective polarization.

In contrast, the policy narrative frame shows a more concentrated distribution toward negative sentiment values, with a narrower spread compared to the other and climate frames. Although limited positive outliers are present, the majority of sentiment observations within the policy frame remain within the negative sentiment range. This concentration of negative sentiment within policy-related discourse may reflect public dissatisfaction with regulatory aspects of carbon trading Bodrožić and Adler (2025).

The economic narrative frame demonstrates a relatively concentrated distribution within negative sentiment values, with limited variation and a small number of neutral or slightly positive outliers. The narrower sentiment spread within this frame indicates a more consistent evaluative pattern compared to other narrative categories. This uniformity of negative sentiment within economic discourse may reflect public concerns about the financial implications of carbon pricing mechanisms Bucur et al. (2024).



**Figure 6.** Narrative Similarity Network

In addition to sentiment variability across narrative frames, the structural relationship between narrative expressions is illustrated in Figure 6, which presents the narrative similarity network. The network visualization demonstrates the presence of multiple narrative clusters, including one dominant central cluster and several smaller isolated clusters. The central cluster represents highly interconnected narrative expressions with strong semantic similarity, while smaller clusters and isolated nodes represent less connected or more distinct narrative expressions within carbon trading discourse.

The presence of both dense clusters and isolated nodes indicates that narrative discourse related to carbon trading is not uniformly structured but instead consists of both highly interconnected narrative communities and more fragmented or independent narrative expressions. The overall network structure suggests heterogeneous narrative connectivity patterns across the discourse dataset, consistent with network-analytic findings on policy discourse fragmentation (Wasserman & Faust, 1994).

### 7. Policy Event Sentiment Shift Analysis

The causal policy event analysis examines changes in public sentiment toward carbon trading before and after the identified policy event period. As presented in Table 2, the average sentiment score during the pre-event period is recorded at -0.677, while the average sentiment score during the post-event period is recorded at -0.699.

**Table 2.** Causal Policy Event Analysis

Metric	Value
Pre Event Sentiment	-0.677
Post Event Sentiment	-0.699
Policy Sentiment Impact	-0.023

The comparison between pre-event and post-event sentiment values indicates a slight decrease in average sentiment following the policy event, with a calculated sentiment impact value of -0.023. This result indicates that overall public sentiment toward carbon trading became marginally more negative after the policy event period. This finding is consistent with research by Bäckstrand and Lövbrand (2019), who observed that policy announcements often trigger short-term negative reactions before publics adjust their evaluations.

The magnitude of the sentiment change is relatively small, indicating that while a directional shift toward more negative sentiment is observed, the overall sentiment structure remains relatively stable across the event boundary. The close proximity of pre-event and post-event sentiment values suggests

that the policy event is associated with a minor sentiment adjustment rather than a substantial shift in overall public evaluation patterns. This stability may reflect entrenched public attitudes toward carbon trading that are resistant to short-term policy signals (Cairney, 2016).

## **B. Discussion**

The overall findings indicate that public discourse surrounding carbon trading is characterized by dominant negative sentiment tendencies, high sentiment variability, and heterogeneous narrative structures across digital communication spaces. These patterns suggest that carbon trading is still perceived as a complex and contested policy instrument among the public. The coexistence of strong negative sentiment clusters alongside positive sentiment groups indicates that public perception is fragmented rather than uniformly supportive or oppositional. This fragmentation aligns with research by Druckman and McGrath (2019), who documented similar polarization patterns in public attitudes toward environmental policies.

The narrative distribution results further show that a large proportion of public discourse does not explicitly align with technical policy, economic, or climate-specific narratives, indicating that public conversations are often embedded within broader social and societal contexts rather than structured policy-oriented discussions. This finding echoes research by Schäfer (2012), who emphasized that online environmental discourse frequently extends beyond formal policy frames to encompass wider social concerns and values.

In addition, the narrative similarity network reveals the existence of clustered discourse communities, suggesting that public interpretation of carbon trading may circulate within segmented communication groups rather than through fully integrated public discourse channels. This segmentation has important implications for policy communication, as different public segments may require tailored communication strategies to effectively reach and engage diverse audiences (Bennett & Segerberg, 2013).

From a policy and governance perspective, the results suggest that carbon trading policy communication may require more adaptive, continuous, and audience-segmented communication strategies. The slightly negative carbon market stability indicator and marginally negative policy communication effectiveness score indicate that public trust formation toward carbon trading policies remains in a relatively sensitive stage. This finding is consistent with research by Fairbrother (2016), who emphasized the importance of trust-building for market-based environmental policy acceptance.

Furthermore, the causal policy event analysis demonstrates that regulatory or policy announcements alone may have limited short-term impact on shifting public sentiment patterns. This suggests that long-term perception change may depend on sustained narrative reinforcement, transparency in policy implementation, and clearer communication of tangible environmental and economic benefits. These implications align with recommendations from Tunca (2026) regarding the need for ongoing public engagement in environmental policy processes.

The findings also highlight the importance of monitoring digital discourse as part of policy feedback mechanisms, as online discourse patterns may provide early signals of public acceptance challenges or emerging narrative resistance toward carbon trading policy implementation. This recommendation is consistent with emerging research on computational policy monitoring Rahman and Fitriyah (2025) and the value of real-time social data for evidence-based policymaking.

## **CONCLUSIONS**

Our analysis paints a clear, if sobering, picture of carbon trading as a socially contested instrument in Indonesia's digital sphere. While negative evaluations dominate, sentiment does not coalesce into a uniform rejection; instead, we find a polarized landscape where strongly positive and neutral clusters persist alongside widespread criticism. More revealing is the narrative structure: public comments rarely engage with the technical mechanics of policy or market economics. They consistently embed carbon trading within broader societal anxieties, such as national development, resource governance, and everyday fairness, which signals a persistent gap between how regulators frame the issue and how ordinary citizens interpret it. Methodologically, this work demonstrates that advanced NLP and

narrative network analysis are not merely academic exercises; they offer a tangible way to map these fragmented interpretive communities and track policy legitimacy in real time.

The governance implications are equally direct. The minimal sentiment shift we observed following a major policy announcement suggests that episodic communication efforts do little to move public trust, which remains fragile. If market-based environmental governance is to gain traction, authorities must move beyond abstract climate targets and invest in sustained, context-aware dialogue that speaks directly to local economic and social concerns. We acknowledge the limitations of a single-platform, language-specific dataset, yet the broader takeaway holds, which carbon market legitimacy is not an institutional given but a continuous social negotiation. Ignoring the messy, everyday conversations happening on digital platforms risks embedding policies in a vacuum, where mistrust compounds and participation falters.

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