Drivers of Social Media Engagement on Organizational Communication on Sustainable Technological Innovation: Insights from Developed and Developing Countries

Swagato Chatterjee, Arpita Ghatak, Anirudh Kumar Meena and Piyush Meena

***Abstract*— Understanding how the public engages with messages from organizations is key to getting people to adopt sustainable technological innovation. This study looks at what drives social media interactions with sustainable technological innovation content in both developed and developing countries using language processing, econometric modeling, and machine learning. The study chose hydrogen fuel cell vehicles as an example. By studying large amounts of social media data, the research finds important themes and factors that shape public engagement. The results show that an ideal balance between simple text and technical information leads to higher engagement. Engagement trends vary by region: short-term issues attract more attention in developed countries, while both short- and long-term energy topics appeal to developing countries. Emotional factors like trust and fear play a big role in engagement across different settings. The study provides insights into how messages from organizations can influence public attitudes toward new sustainable technologies. It also gives practical tips to improve content and boost engagement. This way, organizations and policymakers can make better decisions that promote sustainable technology. Overall, the research helps us understand how communication affects the public's interest in renewable energy.**

***Index Terms*— Sustainable Technological Innovation, social media engagement, Organization-Generated Content, text complexity, emotions, Hydrogen fuel.**

Managerial Relevance Statement:

This study provides engineering managers and policymakers with clear guidance on how to use social media communication to accelerate public acceptance of sustainable technologies such as hydrogen fuel cell vehicles. A key finding is the inverted U-shaped effect of text complexity: messages that are too simple or too technical reduce engagement, whereas moderately complex content maximizes audience response. This challenges the conventional belief that simpler is always better, underscoring the need to balance accessibility with technical depth. The results also reveal cross-country differences: in developed markets, short-term, trust-based messages are most effective, while in developing markets, a mix of short-term benefits and long-term visions stimulates engagement. Practitioners can act on these insights by testing message readability, tailoring narratives by region, and adopting hybrid segmentation that considers both economic classification and technology readiness. Importantly, trust-building through calm, credible tones and selective collaboration with governments, NGOs, and influencers enhances message effectiveness, offering actionable pathways for technology adoption strategies. This paper also contributes to the following SDGs: SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action).

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Supplementary material is shared with this paper for further exploration.

I. INTRODUCTION

As natural resources continue to diminish and the global carbon footprint rises, the demand for innovative solutions that can simultaneously address sustainability challenges and economic growth becomes ever more pressing. In this context, Sustainable Technological Innovation (STI) emerges as a critical necessity. STI is not only about technological advancement but about integrating environmental, economic, and social goals into the development and deployment of new technologies [1]. By linking innovation to sustainability imperatives, STI offers a pathway for balancing growth with ecological responsibility.

STI has demonstrated transformative potential across several domains, including renewable and alternative energy, green fuel, sustainable packaging, and waste management. Each of these innovations contributes not only to reducing ecological degradation but also to fostering long-term economic resilience [2]. For instance, the adoption of renewable energy sources plays a dual role—it drives economic growth while also reducing environmental harm [3]. Over the last decade, the proliferation of renewable energy technologies such as solar power, hydrogen energy, and hydroelectric power highlights how STI has moved from being a conceptual ideal to a practical reality [4]. Taken together, these examples reinforce that STI is a cornerstone for building a sustainable future.

Despite its promise, STI adoption and diffusion remain fraught with challenges. Beyond well-documented barriers such as high upfront investment costs, technological uncertainties, and supply chain complexities, a particularly persistent obstacle is market acceptance and scalability. In many cases, the commercialization of emerging technologies struggles to gain traction, leading to a slower pace of adoption than anticipated [5]. To mitigate such barriers, governments, corporations, and non-governmental organizations (NGOs) employ a range of strategies. Governments often introduce supportive policies such as tax benefits, subsidies,

infrastructural support, and awareness programs. Corporates and NGOs, in turn, engage in initiatives such as innovation management, consumer education, and targeted sales promotions. While these interventions are vital, there remains scope to explore additional levers that can accelerate STI adoption.

One such lever is organization-generated communication (OGC), particularly on new-age platforms like social media. Social media has become a key arena where information, narratives, and public opinion about sustainable technologies are shaped and contested. Existing literature has primarily focused on user-generated content (UGC) in this space, highlighting how public discourse and opinion dynamics influence attitudes toward STIs. However, most of these studies have been concentrated in specific regions or countries and have not given equal attention to the role of OGC [6]. In fact, a limited number of studies address OGC in the context of renewable and sustainable energy, with most focusing narrowly on UGC [7][8]. More critically, prior OGC research has largely treated organizational communication as a monolithic construct, offering limited insight into the content-level mechanisms through which organizations strategically frame sustainable technological innovations to elicit engagement across different institutional and developmental contexts. Such studies did not explain specific content characteristics—such as topical emphasis, emotional tone, sentiment polarity, and message readability—systematically drive user engagement with sustainable technological innovations across heterogeneous institutional contexts. This gap is important because OGC, when strategically crafted and disseminated, plays a central role in shaping consumer perceptions, creating engagement, and ultimately fostering adoption of sustainable innovations.

Against this backdrop, the present study aims to deepen our understanding of OGC in the context of sustainable technologies. Specifically, this research investigates the themes and characteristics of OGC on social media and their influence on user engagement. By comparing OGC across developed and developing countries, the study also highlights how contextual factors shape communication strategies and outcomes. Accordingly, the primary research questions guiding this inquiry are:

a) What are the major themes on which organization-generated-contents are shared in developed and developing countries while promoting a STI?
b) How do such themes and other factors of organization-generated-content lead to user engagement of social media posts related to a STI?
c) What is the role of other content related variables such as complexity, emotion and sentiment?

By addressing these questions, this study contributes to a more nuanced understanding of how OGC can act as a catalyst for STI adoption and engagement, complementing existing policy and market-based approaches.

As an example of STI, we can discuss hydrogen energy. Hydrogen energy is clean, stable, and plays an important role in changing how we use power around the world [9]. The International Renewable Energy Agency (IRENA) predicts that hydrogen energy could make up 6% of all global energy by 2050. They also expect that investments will reach nearly 1.4% of global energy funding by 2030 [10]. Countries are working hard to develop hydrogen energy technologies, especially in new energy vehicles. Hydrogen fuel cell vehicles (HFCVs) are becoming popular because they can go farther, fuel up quickly, and have a cleaner life cycle compared to electric cars [9]. However, despite the environmental advantages of HFCVs, widespread adoption faces multifaceted challenges, including sourcing sustainable energy for vehicle use, advancing hydrogen production and storage technologies, and addressing infrastructure, safety, financial, and policy barriers [11][12]. Overcoming these obstacles is crucial for realizing a clean and sustainable transportation system, which hinges significantly on public perceptions of such clean energy products.

To answer the research questions, we have collected data about the posts on hydrogen fuel shared by various public Facebook pages. We used text mining-based methods such as natural language processing (NLP), topic and sentiment mining followed by econometric and machine learning (ML) modeling to find the key themes of discussion, the key drivers of engagement and the contextual effects of the organization type. We find an optimal level of text complexity, represented by a U-shaped relationship with user interactions, indicating that content should strike a balance between accessibility and informativeness. Developed countries prioritize short-term topics like electric vehicles, while developing countries show interest in both short-term projects and long-term energy planning. Emotions, particularly trust and fear, significantly influence engagement globally, with varying regional emphases on specific topics and emotional tones in driving interaction. The paper theoretically contributes towards the literature on the role of social media in sustainable consumption and to the literature of social media and hydrogen fuel. This is the first paper in this domain which focuses on organization-generated content. Additionally, in terms of managerial implications, the paper also helps officers of marketing, communication, digital marketing, etc. from various types of organizations in developing vs developed countries in creating content strategies to promote STI.

The paper follows the following structure: first we review the literature and identify the gap of the literature. Next, we discuss the methodology proposed followed by the analysis and findings. We further discuss the findings, the theoretical contributions, managerial implications and limitations and future scopes of the study.

II. LITERATURE REVIEW

A. Sustainable Technological Innovation and Social Media

Sustainable technological innovation (STI), blends environmental, economic, and social goals into the growth and use of new technologies. Social media platforms have become important tools for promoting STI. They help share information, connect with people, and create values together

[13]. Research by Han and Yang shows that social media has a big impact on how people choose green lifestyles. Studies have found that contact through social media is linked to adopting these green lifestyles [13]. Value co-creation plays a part in this connection. This means social media helps users to share what they know and their experiences, which in turn encourages sustainable behaviors, as suggested by Du and colleagues [14]. Moreover, text-mining social-media data helps innovation managers with information on consumers, trends, companies and technologies. Han and team have done a literature review showcasing how social media mining can be done in the new product development process [63]. Zhao and team have studied how different types of usage of social media leads to different results in innovation management [64]. Tao and team have shown how the various types of digitalization practices help in innovation [65]. While these studies were rich and comprehensive, they did not focus on STI only. Ozcan and others [15] analyzed microblogs exploring the trends and ideas for sustainable innovation. However, Laurell and Sandström argued, the quality of the data is a significant concern for social media-based analyses [16]. Moreover, adoption of such innovation is still not sure.

Not only for consumers, using social media can lead to better sustainability practices in small and medium-sized businesses too. Borah and team [17] showed that businesses using social media can improve their sustainability performance. Moreover, new technologies like artificial intelligence (AI) and blockchain are changing social media sites. They help these platforms support sustainable technology initiatives. AI helps send personalized content and analyze data well, while blockchain keeps information sharing clear and safe. These improvements help better promote and adopt sustainable technologies on social media. However, challenges remain in using social media for STI. The spread of false information and the common practice of greenwashing can hurt public trust in sustainable ideas. So, organizations need to use smart communication methods to handle online content well and keep their credibility.

In summary, this stream of literature highlights the role of social media as a channel for promoting sustainability, identifying both opportunities (value co-creation, consumer adoption, SME practices) and challenges (data quality, greenwashing). However, most of these studies remain general to STI and do not explicitly consider how specific innovations—such as hydrogen technologies—are communicated or adopted.

B. Social media engagement as the key variable

In the absence of actual adoption data, this study uses consumer engagement on social media posts as a key variable. Engagement with organization-generated content plays a crucial role in driving sales by fostering consumer interaction and amplifying brand visibility. When consumers engage with sustainable technology innovation (STI) content through likes, comments, shares, and other interactions, they signal a positive response, which enhances content reach [18][19]. This engagement not only increases content virality but also helps build loyalty and strengthen customer relationships, as suggested by Kumar and others [20].

Research has established a direct link between social media engagement and social change. For example, engagement has been crucial in vaccination campaigns [21], adoption of contact-tracing apps [22], and the diffusion of electric vehicles in China [23]. Brands like T-Mobile and Wendy's have successfully used social media to engage customers, improving brand perception and boosting sales [24]. Studies show that effective use of social media can significantly impact sales metrics [25][26], driving consumer interest and purchase decisions through enhanced brand salience and product awareness [27].

Social media engagement is pivotal for accelerating the adoption of sustainable technologies. Platforms like Twitter, LinkedIn, and Facebook enable innovators, businesses, and consumers to collaborate and spread awareness about eco-friendly innovations [28] [29]. These platforms facilitate real-time feedback and community-driven support, fostering trust and speeding up adoption [30][31]. Guo and Saxton argued, by mobilizing collective action and advocacy, social media campaigns encourage policymakers and drive investment in sustainable technologies [32]. In this way, social media catalyzes the adoption of sustainable innovations, promoting a more environmentally conscious future.

This stream emphasizes engagement as a measurable proxy for behavioral outcomes, with evidence across health, mobility, and corporate contexts. However, while prior work shows the power of engagement for social change, it often centers on user-generated content (UGC) or brand engagement broadly, with limited attention to organization-generated content (OGC) in the context of STI adoption.

C. Hydrogen fuel as Sustainable Technological Innovation

Hydrogen energy is considered as a clean and sustainable energy source and holds significant potential as a zero-carbon emission energy source, as argued by McPherson and team [33]. Despite its promising prospects, hydrogen technology remains at an early stage of development, grappling with various challenges that require prompt resolution. O'Garra and others suggest, the success of hydrogen technology as a critical component of energy transition relies not only on technical factors—such as technological efficiency and production costs—but also on public acceptance [34]. For hydrogen to play a significant role in energy transition, the technology must be accessible and easily understood by the public [34]. Just as the average person may not fully understand the principles behind internal combustion engines but still drives a car regularly, hydrogen energy needs to be similarly user-friendly. Research focusing solely on corporations, entrepreneurs, environmentally conscious groups, and industrial and scientific associations will not suffice to build a hydrogen-based energy society. Public education and awareness of hydrogen energy are essential to this transition, as suggested by Hienuki and others [35].

Therefore, organizational communication regarding HFCV becomes an important factor for future adoption and growth of HFCVs.

Several studies examined consumer perceptions on HFCV, primarily focusing on U.S. and European markets [36][37]. However, the role of social media in the adoption of HFCV has remained limited. The only study that we found in this context has focused on public opinion of HFCV in China [38]. This geographical limitation in the extant literature creates a gap suggesting a need for further research on how organizational communication in social media can lead to consumer adoption or acceptance of HFCV in developed and developing countries. Our paper fills this gap.

Thus, while hydrogen is recognized as a critical STI, prior literature has mostly concentrated on technical or consumer perception aspects. Very few studies consider the communication mechanisms through which organizations influence public engagement, especially across diverse geographic contexts.

D. Synthesis and Research Gap

Taken together, the reviewed literature can be grouped into three main streams: (i) studies on STI and the role of social media in general, (ii) studies on social media engagement as a driver of adoption and change, and (iii) studies specifically addressing hydrogen fuel technologies. While each stream contributes valuable insights, there are important differences. The first stream establishes the broad potential and challenges of using social media for STI promotion, the second highlights engagement as a measurable proxy for adoption, and the third underscores hydrogen's promise but reveals limited attention to communication and social media.

The key research gap lies at the intersection of these streams: little is known about how organization-generated content (OGC) on social media shapes engagement with hydrogen fuel cell vehicles (HFCVs), particularly when comparing developed and developing country contexts. By addressing this, our study contributes to both the STI communication and technology adoption literatures.

III. DRIVERS OF SOCIAL MEDIA ENGAGEMENT ON ORGANIZATIONAL COMMUNICATION REGARDING STI

A. Text Complexity

As text complexity increases, engagement with social media posts tends to drop, largely due to a reduction in processing fluency. Processing fluency refers to the ease with which individuals process information, with more fluent (i.e., simple) content, generating a more positive affective response [39]. Prior research indicates that this positive effect stemming from fluency often leads to more favorable judgments, including an increased likelihood of liking, commenting on, or sharing content [40]. Indeed, users are more likely to engage with content that requires less cognitive effort to comprehend, as they experience a smoother, more gratifying interaction with the material.

For example, the act of "liking" a post—one of the least effortful and most frequent forms of engagement—has been shown to correlate with more readable, fluently processed content [41]. Similarly, "commenting" and "sharing" behavior, both driven by social interaction and emotional satisfaction [42][43], are also more likely to occur when the content is easily digestible. Therefore, one might predict that more straightforward, less complex texts will generate more overall social media interactions.

However, when considering niche markets or specialized content, such as discussions surrounding high-tech products, the relationship between text complexity and engagement becomes more nuanced. In these contexts, the audience is typically more educated and knowledgeable, with a higher tolerance—if not preference—for complexity. For example, users participating in discussions related to renewable energy are often seeking detailed, in-depth information to guide decisions, or to contribute to a sophisticated dialogue. For such an audience, overly simplified content may reduce engagement, as it fails to meet their expectations for rigor and depth.

Thus, while simpler content may boost engagement for a general audience, increased text complexity, up to a certain point, can enhance engagement for audiences who value detailed, technical information. This phenomenon suggests a potential inverted U-shaped relationship between text complexity and social media engagement with organization generated content of STI, where engagement rises with complexity to an optimal point, beyond which further complexity diminishes engagement. Initially, increasing complexity may attract more thoughtful, high-quality interactions, but as the text becomes overly intricate or dense, it may reach a threshold where even a well-educated audience experiences reduced fluency, leading to a drop in engagement.

H1- The relationship between text complexity and social media engagement on OGC related to STI will follow an inverted U-shaped curve.

B. Topic distribution: Role of Dual Processing Theory and Psychological Distance Theory

According to dual processing theory, as proposed by Kanheman, social media content that appeals to either rational or emotional processing can significantly influence user engagement behaviors [44]. The theory posits two modes of thought: System 1, which is fast, automatic, and emotional, and System 2, which is slow, deliberate, and rational [44]. Swani and others argue that emotional content, processed via System 1, tends to elicit passive social media engagement behaviors (SMEB), such as reading, clicking, and scrolling, as these actions do not require extensive cognitive effort [45]. In contrast, rational content, which demands more cognitive involvement and is processed through System 2, is associated with active SMEB, including actions like liking, sharing, and commenting [45]. Research suggests that emotional appeals, by activating System 1 processing, prompt passive forms of engagement, while rational appeals lead to active engagement

due to the cognitive effort required for System 2 processing [45]. However, passive engagement may precede active engagement, as users first consume content through System 1 before transitioning to more effortful, System 2 behaviors [44]. Therefore, content that appeals to both emotional and rational processing can facilitate varying levels of engagement, with emotional content primarily driving passive behaviors and rational content encouraging active participation, as explained by Carlson and team [46].

According to psychological distance theory, as proposed by Trope and Liberman, individuals are more likely to engage with content that feels temporally, socially, or spatially closer to them [47]. Short-term oriented topics, such as government policies or alternative energy sources, reduce psychological distance, making them feel more immediate and relevant to users. This sense of relevance and urgency typically results in higher social media engagement [46]. On the other hand, long-term or unrelated topics, such as distant technological innovations or future energy projections, increase psychological distance. These topics are perceived as less relevant to users' present concerns, which often leads to reduced engagement because they lack the immediacy needed to capture users' attention [47]. Therefore, organizations seeking to maximize engagement for STIs should focus on evoking uncertain emotions and addressing short-term, actionable topics to drive higher user interaction.

H2a: Different topics will have different relationships with the social media engagement of organizational communication on STI
H2b: Short-term oriented topics related to STI will have stronger relationships with engagement than long-term oriented topics

C. Text sentiment and emotions

Valence and arousal can exert a negative moderating effect on social media engagement when specific emotional combinations reduce the likelihood of active user interaction, even in the context of STIs. Positive valence, which generally increases engagement, and high arousal, which grabs attention, are typically associated with enhanced social media interaction [45]. For instance, content about STIs that highlights exciting technological advancements or environmental breakthroughs with a positive tone may initially capture user interest. However, when positive valence is paired with high arousal—such as overly enthusiastic or excessively optimistic portrayals of the potential of STIs—engagement may paradoxically decrease. According to appraisal theory, high arousal positive emotions can be appraised as overly idealistic and not relevant to current goals [62], leading to lesser engagement. Berger and Milkman suggested that the emotional intensity of this content can overwhelm users, leading to passive consumption rather than active behaviors like commenting or sharing [43]. For example, a post that excessively emphasizes the futuristic benefits of STIs without grounding them in immediate, practical terms may make users feel that the content is too idealistic or far removed from their current concerns, causing them to disengage.

On the other hand, Nelson-field and team found that negative valence is often associated with lower engagement, and low arousal is linked to passive behaviors [48]. Negative high arousal emotions can enhance social media engagement more than negative low arousal emotions due to their ability to provoke immediate reactions. This is in sync with emotional appraisal theory which suggests that high arousal negative emotions can be appraised as goal-relevant and urgent [62], leading to higher engagement. For instance, Lifang and team showed a post about a crisis affecting an STI may evoke urgency or fear, prompting users to engage actively through comments and shares [49]. Conversely, negative low arousal emotions, such as sadness, often lead to passive consumption without further interaction [50]. High arousal emotions create a sense of urgency that drives behavioral responses, while low arousal emotions tend to elicit reflection rather than action [49][50].

This dynamic shows that while positive high-arousal content may seem naturally engaging, its emotional intensity can reduce active participation in the case of STIs by overwhelming users or making the content feel overly idealized. In contrast, low-arousal negative content can encourage more reflective, thoughtful engagement by focusing on real challenges and practical concerns related to STI adoption, prompting deeper interaction through empathetic or contemplative responses.

H3a: Organization generated social media posts on STI with high arousal positive emotions will have lower engagement than those with low arousal positive emotions
H3b: Organization generated social media posts on STI with high arousal negative emotions will have higher engagement than those with low arousal negative emotions

Figure 1 explains our theoretical model.

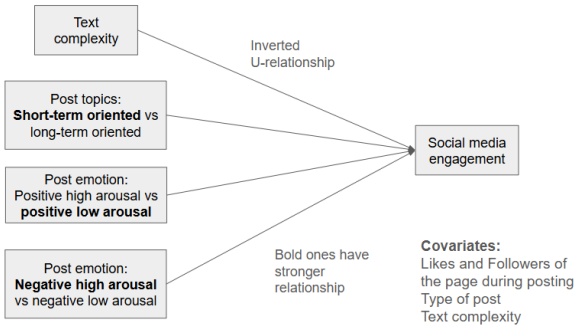

Fig. 1. Theoretical model for social media engagement to organizational communication of sustainable technological innovation

IV. METHODOLOGY

A. Data

We collected the data from Facebook pages using the

Crowdtangle platform. The data contained posts on hydrogen fuel-based vehicles by various facebook pages from February 2022 to February 2024. The keywords used are ("hydrogen fuel" AND ("vehicle" OR "car" OR "transport" OR "train" OR "airplane" OR "traffic" OR "truck"). Hydrogen fuel-based vehicles have seen some prominence and adoption only in this decade and therefore, the above timeline is very relevant for our study. We focused on only such posts which are written in English. To divide the dataset into developed and developing countries, we chose the Top Admin Country feature in the dataset which says which country most of the admins are coming from. We have 4106 observations from developed countries. This consists of 53% from the USA, 21% from the UK, 12% from Australia, 8% from Canada, 2% Japan, 2% from New Zealand and 2% from South Korea. We have 5566 observations from developing countries out of which 25% from India, 10% from China, 10% from Philippines, 5% from South Africa, 4% from Pakistan, 4% from Myanmar and the rest from 72 other countries. The exact methods of country classification, topic modelling, topic wise volume mining, emotion mining, and text complexity mining have been provided in appendix A1 in the supplementary file. The descriptive statistics of the key variables are given in Table S1 and Table S2 of the Supplementary file.

B. Covariates Used

When predicting engagement with a Facebook page, both followers and likes are key factors. Followers represent the potential audience size, as their news feeds often display posts from pages they follow. More followers typically lead to greater visibility and a higher chance of engagement, such as likes, comments, and shares. Likes on a page reflect the audience's interest and loyalty, contributing to higher engagement rates on posts. They also offer insights into past content strategy performance and brand appeal, helping predict future engagement.

The type of post (video, photo, link, etc.) is also crucial in predicting engagement. Different formats attract varying levels of interaction. Videos tend to receive more engagement because they are immersive and capture attention longer, resulting in more likes, comments, and shares [51]. Photos, being visually appealing, often generate quick reactions, like likes and shares [52]. Links, while less interactive, help drive website traffic and have their place in content strategy [53]. Considering post type enhances models by revealing how content format affects engagement, enabling more effective social media strategies.

C. Explanatory Models

To test the above-mentioned hypotheses, we tested four sets of models using poisson regression as the method and count of total interactions as the dependent variable. In model 1, we tested the effects of the covariates (likes on the organization page during posting, followers on the organization page during posting, post type) and the text complexity. In model 2, we include topic distribution variables in the model. In model 3, we also include the overall sentiment and emotion scores. In model 4, we create the final model by dropping variables from model 3 based on correlation and multicollinearity. We keep the quadratic version of Fog-score irrespective of the multicollinearity as it helps us to test the non-linear effect of text complexity on social media engagement.

D. Predictive Models

Explaining how people engage on social media is important for understanding their feelings and behaviors about STIs. But just explaining is not enough. For the purpose of impact, it is important that organizations can use models for their day-to-day decision making. Therefore, for the purpose of robustness check, we have included predictive models in our studies. Organizations need to use predictive models to see future engagement trends and improve their communication plans. These models provide useful insights that help organizations use their resources better, adjust their messages, and engage with their audiences more. By predicting future interactions from past data, stakeholders can be ready and create better engagement strategies.

In our study, we used four predictive modeling methods: Poisson regression, Random Forest, Support Vector Regression (SVR), and XGBoost. We picked each of these methods because of their strong points in working with different types of data. Poisson regression is good for count-data. It works well for checking social media engagement measured by interactions or reactions. Random Forest is helpful because it can handle large datasets and avoids problems with overfitting. This means it can work better with new data. We included SVR to find non-linear patterns in the data, which improves our model's flexibility. XGBoost is fast and works very well, making it a strong choice for tough datasets. Brief talks about these algorithms are in the discussion part of the extra file.

To assess the effectiveness of these models, we utilized both in-sample and out-of-sample Root Mean Square Error (RMSE) metrics. We tried four versions of the models, namely, baseline model, "baseline + readability" model (covariates and Fog Score, similar to Model 1 in explanatory model), "baseline + readability + topic distribution" model (covariates, Fog Score and Topic Volumes, similar to model 2 in explanatory model), "baseline + readability + topic distribution + emotions" model (covariates, Fog Score, Topic Volumes and emotions, similar to model 3 in explanatory model). As correlation and multicollinearity does not affect predictive power of the ML models, we did not create a predictive model in sync with model 4 of the explanatory model. This dual approach allowed us to evaluate how well our models performed not only on the training data but also on unseen data, thereby testing their generalizability and predictive accuracy. Furthermore, we explored the feature-importance to identify which variables significantly influence

social media engagement. This analysis provides insights into the specific elements of posts that resonate with audiences.

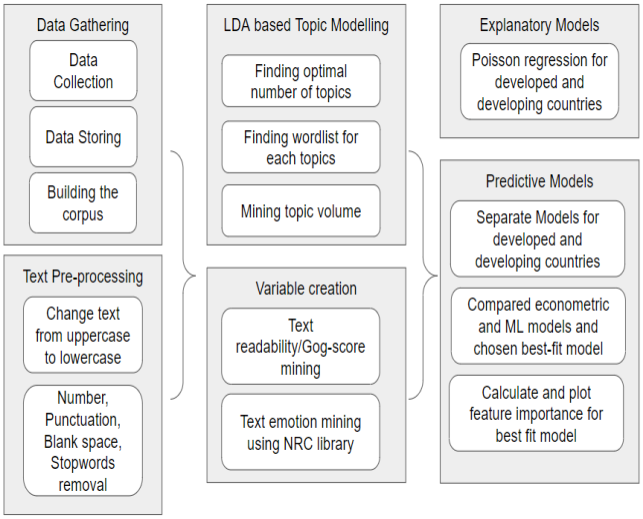

Fig. 2. The steps followed in the methodology and analysis

Additionally, we examined partial dependency curves to visualize the relationship between key features and engagement outcomes. These curves illustrate how changes in predictor variables impact predicted engagement levels, offering a more intuitive understanding of the factors driving social media interactions. By integrating both explanatory and predictive modeling approaches, our study not only clarifies current patterns of engagement but also equips organizations with the tools needed to forecast and enhance future interactions with their audiences. The overall methodology has been explained in further detail in Figure 2.

V. FINDINGS

A. For Developed Countries

1) Results of topic modeling

Based on figure S1 in the supplementary file, we found 12 topics from the posts from organizations of developed countries. The word-list corresponding to the topics are given in Table 1. Short term-oriented topics were Topic 3, 4, 6, 8,11 and 12.

TABLE 1
KEY TOPICS AND BAG OF WORDS FROM LDA ON POSTS FROM DEVELOPED COUNTRIES

Topic #	Topic Name	Words
Topic 1	Rocket Launches and Space Exploration	['launch', 'rocket', 'leak', 'space', 'fire', 'flight', 'liquid', 'moon']
Topic 2	Astronomy and Celestial Phenomena	['star', 'light', 'water', 'sun', 'life', 'carbon', 'image', 'high']
Topic 3	Electric Vehicles	['cell', 'electric', 'vehicle', 'engine', 'powered', 'car', 'nikola']
Topic 4	Power and Health Performance	['power', 'food', 'performance', 'gut', 'health', 'process', 'go']
Topic 5	Nuclear Fusion and Water Power	['water', 'nuclear', 'fusion', 'power', 'reactor', 'energy']
Topic 6	Battery Technology and Toxicity	['battery', 'lithium', 'use', 'toxic', 'electricity', 'ev', 'metal', 'panel']
Topic 7	Renewable Energy and Carbon Reduction	['energy', 'power', 'green', 'renewable', 'gas', 'solar', 'plant', 'carbon', 'wind']
Topic 8	Electric Aircraft and Aviation	['aircraft', 'plane', 'aviation', 'flight', 'flying', 'like', 'great']
Topic 9	Future Clean Energy Technologies	['energy', 'power', 'cell', 'clean', 'new', 'upcoming', 'technology', 'future', 'emission']
Topic 10	Gas Products and Visionary Concepts	['gas', 'water', 'product', 'vision', 'powered', 'oil', 'concept']
Topic 11	Government Policies and State Initiatives	['government', 'state', 'labor', 'policy', 'initiate', 'step']
Topic 12	Electric Cars and Sustainable Transportation	['vehicle', 'electric', 'car', 'powered', 'cell', 'new', 'state', 'air', 'gas']

2) Explanatory Models

Table 2 reports the results of the poisson regression. In model 1 to model 3, the AIC values drop suggesting improving fit of the model. Model 4 has a little lower fit, however, all variables included are free from multicollinearity issues. In Model 4, we find that Fog Score has a positive relationship with total interactions (β=0.02, $p<0.001$ for Model 4), but the quadratic term of Fog Score, although small, has a negative relationship (β=-0.00, $p<0.001$ for Model 4). This suggests an inverted U relationship between Fog Score or text complexity and total interactions (social media engagement), supporting H1.

In Model 2, we included topic related variables. None of the topic related variables were dropped till Model 4 and therefore, we choose Model 4 results to interpret the relationship between topics and social engagement. We have kept Topic 1 ("Rocket Launches and Space Exploration") as our reference point. The top 3 most important topics were "Battery Technology and Toxicity"(Topic 6) (β=2.13, $p<0.001$ for Model 4), "Electric Aircraft and Aviation" (Topic 8) (β=1.25, $p<0.001$ for Model 4), and "Electric Cars and Sustainable Transportation" (Topic 12) (β=0.86, $p<0.001$ for Model 4). The top 3 topics were short-term oriented. The lowest 4 topics in terms of relationship strength with engagement were "Astronomy and Celestial Phenomena" (Topic 2) (β=-0.16, $p<0.001$ for Model 4), "Power and Health Performance" (Topic 4) (β=-0.32, $p<0.001$ for Model 4), "Government Policies and State Initiatives" (Topic 11) (β=-1.56, $p<0.001$ for Model 4) and "Rocket Launches and Space Exploration" (Topic 1). Out of these, two are short-term and two are long-term. The rest have higher relationship strength than Topic 1, such as "Electric Vehicles" (Topic 3) (β=0.67, $p<0.001$ for Model 4), "Nuclear Fusion and Water Power" (Topic 5) (β=0.28, $p<0.001$ for Model 4), "Renewable Energy and Carbon Reduction"(Topic 7) (β=0.30, $p<0.001$ for Model 4), "Future Clean Energy Technologies" (Topic 9) (β=0.28, $p<0.001$ for Model 4), "Gas Products and Visionary Concepts" (Topic 10) (β=0.56, $p<0.001$ for Model 4). The average relationship of all short-term oriented topics was also higher

than those of long-term oriented topics. Therefore, the result supports H2a and H2b.

Finally, among positive emotions, anticipation (β=0.1, $p<0.001$ for Model 4), a low arousal emotion, has a stronger relationship than that of surprise (β=-0.02, $p<0.001$ for Model 4), a high arousal emotion. Therefore, H3a is supported. Among the negative emotions, fear (high arousal) has the highest relationship with engagement (β=0.04, $p<0.001$ for Model 4), followed by disgust (high arousal) (β=-0.06, $p<0.001$ for Model 4) and sadness (low arousal) (β=-0.01, $p<0.001$ for Model 4). This supports H3b.

TABLE 2
THE RESULT OF POISSON REGRESSION FOR DEVELOPED COUNTRIES

	Model1	**Model 2**	**Model3**	**Model4**
(Intercept)	6.51***	5.823***	5.698***	5.728***
Likes.at.Posting	0***	0***	0***	
Followers.at.Posting	-0***	-0***	-0***	0***
TypeLive Video Complete	-1.28***	-1.1***	-1.13 ***	-1.18***
TypeLive Video Scheduled	1.96***	2.36***	2.42***	2.39***
TypeNative Video	0.17***	0.29***	0.26***	0.16***
TypePhoto	0.16***	0.29***	0.19***	0.10***
TypeStatus	0.53***	0.41***	0.61***	0.49***
TypeVideo	-0.28***	-0.32***	-0.17***	-0.21***
TypeYouTube	-0.76***	-0.66***	-0.56***	-0.55***
FOG_Score	-0.01***	0.02***	0.02***	0.02***
FOG_Score^2	0.00***	-0.00***	-0.00***	-0.00***
Topic_2_Distribution		0.34***	-0.01	-0.16***
Topic_3_Distribution		0.54***	0.74***	0.67***
Topic_4_Distribution		-0.68***	-0.31***	-0.32***
Topic_5_Distribution		0.43***	0.28***	0.28***
Topic_6_Distribution		2.25***	2.26***	2.13***
Topic_7_Distribution		0.11***	0.31***	0.30***
Topic_8_Distribution		1.12***	1.32***	1.25***
Topic_9_Distribution		0.02***	0.3***	0.28***
Topic_10_Distribution		0.30***	0.52***	0.56***
Topic_11_Distribution		-0.96***	-1.74***	-1.56***
Topic_12_Distribution		0.74***	0.92***	0.86***
Positive			-0***	
Negative			-0***	
Anticipation			0.08***	0.1***
Trust			0.07***	
Joy			-0.08***	
Surprise			0.00***	-0.02***
Fear			0.02***	0.04***
Anger			0.01***	
Disgust			-0.05***	-0.06***
Sadness			-0.11***	-0.1***
AIC	10831553	10144272	9470997	9646725

3) Predictive Models

The predictive models ensure the robustness of the results obtained from the explanatory models. Table 3 gives the comparative performance of the predictive algorithms.

TABLE 3
RESULTS OF IN-SAMPLE AND OUT-SAMPLE FIT OF VARIOUS PREDICTIVE ALGORITHMS FOR DEVELOPED COUNTRIES

Algorithm	**Model**	**In-sample RMSE**	**Out-sample RMSE**
XGBoost	Baseline	1105	7000
XGBoost	Baseline + Readability	554	3120
XGBoost	Baseline + Readability + Topic Distribution	293	4139
XGBoost	Baseline + Readability + Topic Distribution + Emotion	280	5225
Random Forest	Baseline	1811	4898
Random Forest	Baseline + Readability	1784	3764
Random Forest	Baseline + Readability + Topic Distribution	1787	3056
Random Forest	Baseline + Readability + Topic Distribution + Emotion	1803	3171
SVR	Baseline	4581	2551
SVR	Baseline + Readability	4581	2551
SVR	Baseline + Readability + Topic Distribution	4581	2551
SVR	Baseline + Readability + Topic Distribution + Emotion	4581	2551
Poisson Regression	Baseline	4548	2479
Poisson Regression	Baseline + Readability	4548	2479
Poisson Regression	Baseline + Readability + Topic Distribution	4548	2479
Poisson Regression	Baseline + Readability + Topic Distribution + Emotion	4548	2479
Poisson Deep Regression	Baseline	3165	2289
Poisson Deep Regression	Baseline + Readability	3165	2289
Poisson Deep Regression	Baseline + Readability + Topic Distribution	3165	2289
Poisson Deep Regression	Baseline + Readability + Topic Distribution + Emotion	3165	2289

XGBoost shows sign of over-fitting. Poisson Regression, Poisson Deep Regression and SVR have not improved by including more variables. We have chosen such an algorithm as the best which has a balance between in-sample and out-sample prediction accuracy. Based on the data shown, Random Forest has been chosen to be the best model in terms of predictive power. Figure 3 gives the feature importance of various predictors while predictive social media engagement of the users. Figures S3.1 to S3.6 in the supplementary file

gives the partial dependence curves of various variables in the above-mentioned model. We found that the major variables for explaining total interactions are different from those which predict it better. The top features in terms of predictive importance will be "Government Policies and State Initiatives" (Topic 11), "Future Clean Energy Technologies" (Topic 9), "Battery Technology and Toxicity"(Topic 6), "Electric Vehicles" (Topic 3) and “Gas Products and Visionary Concepts" (Topic 10), which has mix of short-term and long-term topics. All these topics have positive relationships with social media engagement. Text readability (Fog Score) does not come among the top 10 variables in terms of predictive importance. Trust and anticipation (positive low arousal emotion) has higher predictive power than joy and surprise (positive high arousal emotions). Among negative emotions, fear and anger (high arousal) are more important.

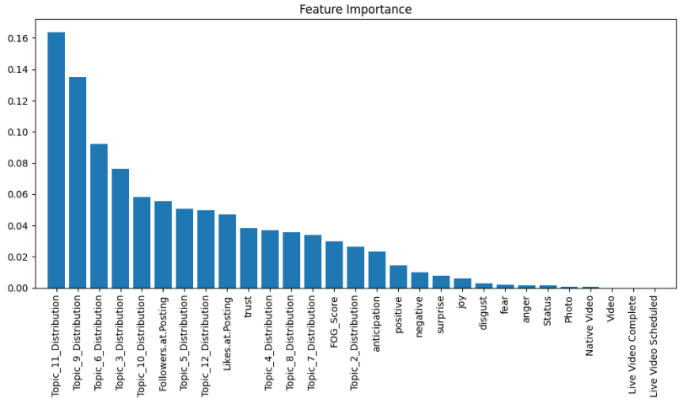

Fig. 3. Feature importance for predicting engagement in developed countries

B. For Developing Countries

1) Results of Topic Modelling

Based on figure S2 in the supplementary file, we identified 11 topics from posts by organizations in developing countries. The wordlists corresponding to these topics are detailed in Table 4 of the supplementary file. In the developing country perspective hydrogen fuel is still in its nascent stage and therefore most of the topics are futuristic and long-term oriented. The only short-term oriented topics were topics 1, 4, 8, and 11.

TABLE 4
KEY TOPICS AND BAG OF WORDS FROM LDA ON POSTS FROM DEVELOPING COUNTRIES

Topic #	Topic Name	Words
Topic 1	Government Green Energy Projects	['green', 'minister', 'project', 'government', ‘policy’, 'energy', 'power']
Topic 2	University Research and Online Resources	['research', 'link', 'university', 'student', 'act', 'missing', 'science']
Topic 3	Transportation Safety and Gas Technology	['bus', 'safety', 'cell', 'train', 'powered', 'engineer', 'service', 'gas']
Topic 4	Water Advocacy and Petroleum Products	['great', 'petroleum', 'need', 'water', 'product', 'godmother']
Topic 5	Astronomy and Celestial Bodies	['star', 'gas', 'correct', 'sun', 'image', 'nebula', 'earth']
Topic 6	Global Renewable Energy Initiatives	['energy', 'power', 'renewable', 'green', 'wind', 'gas', 'project', 'country']
Topic 7	Water Systems and Nuclear Power	['water', 'system', 'power', 'used', 'nuclear', 'high', 'space']
Topic 8	Electric Vehicles and Battery Technology	['vehicle', 'car', 'cell', 'electric', 'engine', 'powered', 'truck', 'battery', 'new']
Topic 9	Future Energy Technologies	['energy', 'technology', 'power', 'cell', 'future', 'green', 'solution']
Topic 10	Oil Refining and Gas Products	['unit', 'oil', 'product', 'gas', 'refinery', 'distillation', 'crude', 'convert', 'process', 'molecule']
Topic 11	Global Governance and Public Opinion	['people', 'government', ‘public’, ‘share’, ‘global’, 'would', 'world']

2) Explanatory Models

Table 5 reports the results of the poisson regression. In line with the results of developed countries, in this case too, in all the models (Model 1 to Model 4), we find that Fog Score has a positive relationship with total interactions (β=0.1, $p<0.001$ for Model 4), but the quadratic term of Fog Score, although small, has a negative relationship (β=-0.00, $p<0.001$ for Model 4). This suggests an inverted U relationship between Fog Score or text complexity and total interactions (social media engagement), supporting H1.

Here, we took "Government Green Energy Projects” (Topic 1) as reference. The three most important topics were "Electric Vehicles and Battery Technology" (Topic 8) (β=1.64, $p<0.001$ for Model 4), "Government Green Energy Projects” (Topic 1) and "Future Energy Technologies" (Topic 9) (β=-0.09, $p<0.001$ for Model 4). The middle topics were: "Water Advocacy and Petroleum Products" (Topic 4) (β=-0.33, $p<0.001$ for Model 4), "Astronomy and Celestial Bodies” (Topic 5) (β=-0.34, $p<0.001$ for Model 4), "Global Renewable Energy Initiatives" (Topic 6) (β=-0.13, $p<0.001$ for Model 4), "Water Systems and Nuclear Power" (Topic 7) ((β=-0.18, $p<0.001$ for Model 4). The least important topics were: "University Research and Online Resources” (Topic 2) (β=-0.1.42, $p<0.001$ for Model 4), "Transportation Safety and Gas Technology" (Topic 3) (β=-0.75, $p<0.001$ for Model 4), "Oil Refining and Gas Products" (Topic 10) (β=-0.63, $p<0.001$ for Model 4) and "Global Governance and Public Opinion" (Topic 11) (β=-0.97, $p<0.001$ for Model 4). We found mixed results in terms of topic’s orientation and engagement. While topic 11 (short-term) is the least important, topic 8 and topic 1 were most important. However, the average relationship-strength of the short-term topics will have no difference from the average relationship-strength of the long-term topics. Therefore, although H3a is supported, H3b was not supported by our results, in the context of developing countries.

Finally, among positive emotions, trust (β=0.01, p<0.001 for Model 4), a low arousal emotion, has stronger relationship than that of joy (β=-0.09, p<0.001 for Model 4), a high arousal emotion. Therefore, H3a is supported. Among the negative emotions, fear (high arousal) has the highest relationship with engagement (β=0.05, p<0.001 for Model 4), followed by anger (high arousal) (β=-0.04, p<0.001 for Model 4), disgust (high arousal) (β=-0.04, p<0.001 for Model 4) and sadness (low arousal) (β=-0.05, p<0.001 for Model 4). This supports H3b.

TABLE 5
THE RESULT OF POISSON REGRESSION FOR DEVELOPING COUNTRIES

	Model1	**Model 2**	**Model3**	**Model4**
(Intercept)	5.55***	4.86***	5.07***	5.17***
Likes.at.Posting	0***	0***	0***	
Followers.at.Posting	0***	0***	0***	0***
TypeLive Video Complete	0.08***	1.09***	1.09***	0.94***
TypeNative Video	0.25***	0.4***	0.41***	0.27***
TypePhoto	0.68***	1.01***	1.01***	0.93***
TypeStatus	-0.48***	0.28***	0.35***	0.21***
TypeVideo	-0.28***	-0.58***	-0.56***	-0.82***
TypeYouTube	-1.43***	-1.41***	-1.44***	-1.6***
FOG_Score	0.07***	0.12***	0.11***	0.1***
FOG_Score^2	-0.00***	-0.00***	-0.00***	-0.00***
Topic_2_Distribution		-1.74***	-1.8***	-1.42***
Topic_3_Distribution		-0.44***	-0.58***	-0.75***
Topic_4_Distribution		-1.11***	-0.31***	-0.33***
Topic_5_Distribution		-1.21***	-1.02***	-0.34***
Topic_6_Distribution		-0.3***	-0.27***	-0.13***
Topic_7_Distribution		-0.3***	-0.54***	-0.18***
Topic_8_Distribution		1.51***	1.35***	1.64***
Topic_9_Distribution		-0.01	-0.11***	-0.09***
Topic_10_Distribution		-0.81***	-1.29***	-0.63***
Topic_11_Distribution		-1.77***	-1.47***	-0.97***
Positive			0.05***	
Negative			0***	
Anticipation			-0.01***	
Trust			-0.05***	0.01***
Joy			-0.19***	-0.09***
Surprise			0.15***	
Fear			0.03***	0.05***
Anger			-0.08***	-0.04***
Disgust			-0.07***	-0.04***
Sadness			-0.04***	-0.05***
AIC	17290639	15857640	15493306	16901194

3) Predictive Models

Following the same method of that for developed countries, in this case also we found random forest to be the best choice of predictive algorithm. XGBoost shows the sign of overfitting. Support Vector Regression, Poisson Regression and Poisson Deep Regression show underfitting and they do not improve over adding more variables. Only random forest regressor shows balance in-sample and out-sample performance and improve performance as we add the independent variables along with the covariates. Table 6 gives the model predictive performance comparisons and Figure 4 gives the feature importance scores for random forest models.

TABLE 6
RESULTS OF IN-SAMPLE AND OUT-SAMPLE FIT OF VARIOUS PREDICTIVE ALGORITHMS FOR DEVELOPING COUNTRIES

Algorithm	**Model**	**In-sample RMSE**	**Out-sample RMSE**
XGBoost	Baseline	3689	3099
XGBoost	Baseline + Readability	924	4185
XGBoost	Baseline + Readability + Topic Distribution	360	2785
XGBoost	Baseline + Readability + Topic Distribution + Emotion	338	2658
Random Forest	Baseline	2202	3500
Random Forest	Baseline + Readability	2134	3896
Random Forest	Baseline + Readability + Topic Distribution	2457	3462
Random Forest	Baseline + Readability + Topic Distribution + Emotion	2380	3184
SVR	Baseline	6613	2404
SVR	Baseline + Readability	6613	2404
SVR	Baseline + Readability + Topic Distribution	6613	2404
SVR	Baseline + Readability + Topic Distribution + Emotion	6613	2404
Poisson Regression	Baseline	6581	2339
Poisson Regression	Baseline + Readability	6581	2339
Poisson Regression	Baseline + Readability + Topic Distribution	6581	2339
Poisson Regression	Baseline + Readability + Topic Distribution + Emotion	6581	2339
Poisson Deep Regression	Baseline	2344	1878
Poisson Deep Regression	Baseline + Readability	2344	1878
Poisson Deep Regression	Baseline + Readability + Topic Distribution	2344	1878
Poisson Deep Regression	Baseline + Readability + Topic Distribution + Emotion	2344	1878

Figures S4.1 to S4.6 in the supplementary file gives the partial dependence curves of various variables in the above-mentioned model. We found likes and followers of the page at posting is the most important variable followed by "Global Renewable Energy Initiatives" (Topic 6), "Electric Vehicles and Battery Technology" (Topic 8), "Future Energy Technologies" (Topic 9). Most of these variables mentioned

here have positive relationships with engagement. Two of these top 3 are long-term oriented topics. Moreover, among positive emotions joy (high arousal emotion) and among negative emotions anger and fear (high arousal emotions) are most important. Text complexity has good predictive ability in the case of developing countries as it comes in top 10 factors in terms of importance. The partial dependence plot shows that at Fog Score = 20 the engagement maximizes.

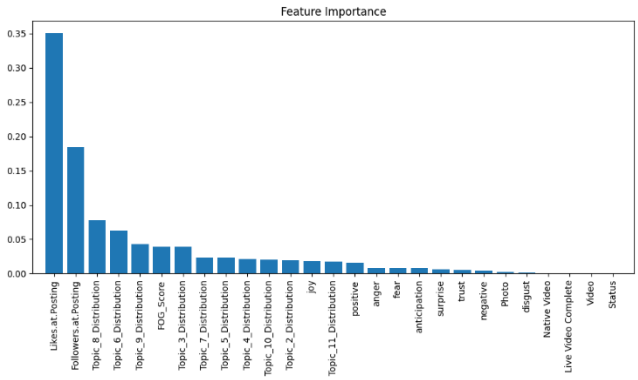

Fig. 4. Feature importance for predicting engagement in developing countries

C. Country-wise analysis

To do a robustness check of our models and hypotheses and to get country level insight about the strategies, we analyzed the explanatory models for 4 countries: UK and USA among the developed countries and India and China among the developing countries. This choice of country is based on data availability (top 2 countries based on data availability are chosen). These are also part of the biggest economies of the world. The results show decent support for our hypotheses. The detailed results are presented in Table S3 and S4 in the supplementary file. The discussions of the results are done in the supplementary file (Page 19 and 20, Discussions S3 and S4).

VI. DISCUSSIONS

A. General discussions

The results of this study provide better understanding of how different factors influence social media engagement with OGC on STI across developed and developing countries with special focus on hydrogen fuel cell vehicle (HFCV).

(a) What are the major themes on which organization-generated-content are shared in developed and developing countries while promoting a STI?
(b) How do such themes and other factors of organization-generated-content lead to user engagement of social media posts related to a STI?

Table 1 and Table 4 summarize the major themes on which OGC are shared in developed and developing countries while promoting STIs. Topic modeling and econometric analysis reveals interesting regional variations. In developed countries, short-term topics such as electric vehicles, battery technology, and aviation are more engaging than long-term, futuristic topics. This is in line with our expectations as discussed in the hypotheses-development section. This also aligns with the higher awareness and readiness for advanced technologies in these markets, where consumers are more likely to interact with content that offers immediate relevance and benefits [54]. Conversely, in developing countries, the results are more mixed. While short-term topics like government green energy projects and battery technology are important, long-term topics such as future energy technologies also resonate. This reflects the developing countries' focus on long-term infrastructure development and energy planning [55].

(c) What is the role of other content related variables such as complexity, emotion and sentiment?

Our findings highlight the critical role of text complexity in driving engagement with sustainable technologies. While previous studies suggest a negative relationship between complexity and engagement, we identify an inverted U-shaped relationship between the Fog Score and user interactions. This suggests that an optimal level of complexity maximizes engagement, balancing accessibility with informativeness. Notably, the optimal complexity is lower in developed countries, where hydrogen fuel cell vehicles (HFCVs) are a more immediate reality. In developing countries, HFCV remains a niche topic, primarily engaging technology enthusiasts and policymakers rather than the broader public.

Emotion also plays a crucial role in engagement with sustainable innovations. Positive emotions, particularly trust, significantly influence user interactions across both developed and developing nations, aligning with prior research on the role of trust in environmental communication [56]. Among negative emotions, fear proves most effective in driving engagement, indicating that content emphasizing risks and the consequences of inaction can capture public attention.

Furthermore, our predictive analysis identifies random-forest as the most effective algorithm for modeling social media engagement. Key drivers vary by region, reflecting distinct economic and technological contexts. These insights provide actionable guidance for tailoring digital communication strategies.

B. Theoretical and Methodological contributions

This study advances theory at the intersection of social media, organizational communication, and sustainable technology adoption, with a specific focus on hydrogen fuel cell vehicles (HFCVs). Several theoretical perspectives are extended through the findings:

1) Organizational Communication and Technology

Adoption

Primarily the paper contributes to the literature stream on usage of social media for sustainable technological innovation [13, 14, 15, 16]. A central theoretical contribution lies in shifting the focus from user-generated content (UGC) to organization-generated content (OGC). Prior research on hydrogen fuel and sustainable technological innovations (STIs) has predominantly emphasized UGC or consumer perceptions within markets [7][8][37][38]. By foregrounding OGC, this study extends organizational communication theory by conceptualizing organizations as active participants shaping public perceptions, rather than as passive information providers. This reconceptualization highlights the strategic role of OGC in influencing engagement and adoption of sustainable technologies [18][24]. It also contributes to theories of technology adoption in sustainable contexts by demonstrating how structured organizational messaging can drive public discourse and engagement with renewable technologies [6].

2) Information Processing Theory

The analysis of text complexity provides an extension of theories of information processing. Prior research suggests that simplified content is more engaging because of ease of processing [39][40]. This study, however, identifies an inverted U-shaped relationship between text complexity and engagement. The finding demonstrates that moderate complexity maximizes engagement, especially for high-tech product communication where audiences require both informational depth and accessibility [41]. This adds nuance to existing information processing perspectives by showing that optimal engagement in sustainable innovation contexts depends on balancing complexity and clarity.

3) Dual-Process Theory and Psychological Distance Theory

The study also advances dual-process theory by showing that emotional content drives passive engagement, while rational, detailed content stimulates active interaction [44][45]. Moreover, drawing on psychological distance theory, the results indicate that short-term, locally relevant topics foster greater engagement than long-term or abstract themes [47]. Together, these insights extend theories of message processing by contextualizing them within sustainable innovation communication, highlighting how different cognitive routes (emotional vs. rational; proximal vs. distal) differentially affect social media engagement with STI content. These findings enhance the theoretical framework for social media analytics in innovation management, particularly for sustainable innovation communication [15][57].

4) Literature on Emotional Engagement in Technology Diffusion and Emotion Appraisal Theory

The findings also contribute to the literature on emotional engagement strategies in social media-based diffusion of innovations. Prior studies suggest that high-arousal positive content attracts initial attention but may eventually reduce engagement if perceived as excessively optimistic [43]. This study confirms that overuse of high-arousal positive content diminishes active engagement, whereas high-arousal negative content; such as highlighting environmental crises stimulates immediate user responses [50]. This extends theoretical understanding of the role of emotional arousal in engagement, particularly in the diffusion of sustainable technologies. This also extends the applications of emotion appraisal theory in the context of STI adoption [62].

5) Regional Variations in Engagement Theory

The study also contributes to theories of engagement in sustainability and innovation by uncovering regional variations. In developed countries, short-term topics and trust-driven engagement dominate, whereas in developing countries, both short- and long-term topics matter, and anger-driven engagement is more influential. These findings advance cross-cultural perspectives within engagement theory and provide new insights into how emotional and temporal framing of organizational messages interact with audience context [61].

6) Methodological Contributions

Additionally, it contributes to the application of text mining and natural language processing (NLP) in innovation research, with a particular focus on STI. Prior literature has employed NLP techniques to identify technological innovation trends [15][57][58] and explored the role of social media analytics in innovation management [59]. However, these studies have rarely leveraged AI-based NLP methods to analyze the drivers of technology adoption. By utilizing social media engagement as a proxy for STI adoption, this study offers a novel contribution to the field of technology innovation and adoption research.

The study also advances the STI adoption literature by incorporating predictive modeling into engagement analysis [61]. By extending traditional econometric approaches with machine learning models, this research provides new insights into how engagement drivers differ between developed and developing countries. The finding that short-term topics drive engagement in developed countries, while a mix of short- and long-term topics matter in developing countries, adds a novel perspective to engagement theory. Additionally, the distinction between trust-driven engagement in developed markets and anger-driven engagement in developing markets underscores regional variations in content reception and emotional influence. This knowledge contributes towards literature in the intersections of sustainability and innovation [61].

C. Managerial Implications

The study's findings offer valuable insights for organizations promoting sustainable technologies across diverse global markets. It emphasizes the need for tailored communication strategies that resonate with audiences in both developed and developing nations, thereby enhancing social media engagement and fostering positive perceptions of sustainable technologies.

One key takeaway is the significance of content complexity in user engagement. The study reveals an inverted U-shaped relationship between text complexity (Fog Score) and engagement, suggesting that content should strike a balance between technical detail and accessibility. In developed countries, where familiarity with various sustainable technologies is higher, moderately complex messages can stimulate active engagement. Conversely, in developing nations, educational content should avoid excessive technical jargon while educating audiences about sustainable technologies. Practitioners can apply this by testing message readability levels before campaigns and by tailoring technical depth to the audience segment, for example, using simpler narratives for the mass public while retaining moderate complexity for policy or industry stakeholders.

Moreover, the study highlights the effectiveness of short-term oriented content themes in developed countries, such as immediate benefits of sustainable technology adoption including emission reduction and government initiatives. In contrast, developing countries show engagement with both short-term benefits and long-term visionary topics, underscoring the importance of a balanced content strategy that addresses local immediate needs and future potential. However, practitioners should be careful about the categorization of the country while creating a strategy. The categorization of developed vs developing countries is done by various organizations (in our case, we used that of UN and IMF). While such categorization is done by socio-economic background, sometimes it can also be politically motivated. Moreover, the relevant technological advancement may not be always in sync with socio-economic reality. Therefore, caution should be practiced while implementing the content strategy. Managers may therefore consider hybrid segmentation approaches, combining economic classification with indicators such as technology readiness or environmental policy goals, to fine-tune their messaging.

Emotionally, the study underscores the role of trust and caution in content tone across all markets. Calm and positive sentiments enhance engagement more than strong emotions like surprise or joy, suggesting that credibility and reliability are crucial in messaging. Conversely, strategically invoking negative emotions like fear can effectively highlight urgent environmental issues, albeit requiring moderation to avoid backlash or negative perceptions. For practice, this means campaigns should be carefully balanced: emphasizing reliability and optimism in brand voice while using controlled doses of fear appeals in policy-driven or issue-focused messaging.

Furthermore, the study emphasizes the impact of organizational types on message reception, advocating for collaborative efforts between government and business sectors. Such partnerships can align communication strategies with national sustainability goals, enhancing public trust and participation, particularly in developing regions where government-led initiatives often garner significant public support. Industry practitioners should also consider working with NGOs and influencers to amplify credibility and reach, especially in areas where trust in corporate or governmental communication may be limited.

From a strategic standpoint, leveraging predictive models can optimize social media strategies regionally. In developing countries, focusing on metrics like likes and followers while prioritizing locally relevant content enhances engagement. Conversely, in developed markets, balancing short- and long-term topics and leveraging emotions like trust for brand loyalty are critical strategies. Managers can operationalize this by running A/B tests on message framing and monitoring engagement patterns with predictive analytics tools, allowing them to refine strategies dynamically.

Overall, these findings provide actionable insights for managers and policymakers to refine their communication approaches, foster greater public acceptance of sustainable technologies, and align messaging with diverse audience needs and expectations worldwide. In practical terms, organizations should view social media not only as a promotional tool but as a strategic lever for shaping public discourse, building trust, and accelerating adoption of sustainable technological innovations.

D. Limitations and Future Scope

Despite offering valuable insights, this study has several limitations. First, the research focuses solely on social media data, which may not fully capture offline public opinion or engagement with sustainable technological innovations. Social media platforms tend to attract specific user demographics, often younger, more tech-savvy individuals, which may skew the findings. Future studies could broaden the scope by incorporating offline surveys, interviews, or other data sources to get a more holistic understanding of public sentiment.

Second, while the study successfully identifies key topics and emotional drivers of engagement, it does not delve into the nuances of how different cultural or socioeconomic factors may influence these patterns. For example, developing countries exhibit a diverse range of developmental stages, regulatory environments, and public attitudes towards renewable energy, which may have a significant impact on engagement with STI. Future research could explore cultural dimensions, such as individualism vs. collectivism [60], or income disparities, shape public interactions with sustainable technologies. Moreover, we used computational linguistics for emotion mining and performed reliability checks by manual annotators. However, future researchers can also use semi-supervised method for contextual emotion mining.

One important drawback of our method is that we have chosen International Monetary Fund (IMF) and United Nations' (UN) definitions, while classifying the countries in developing and developed countries. Such classification can also be motivated by politics and other related goals. Therefore, future researchers can study this topic from multiple other meaningful classifications. Moreover, while English-language pages may attract a cross-national audience, this does not undermine our content-level analysis. Any international participation is likely to introduce noise and thus attenuate observed differences. Consequently, the detected differences between developed and developing country pages represent conservative estimates of institutional variation in sustainability communication strategies.

Another limitation is the temporal scope of the analysis. Social media conversations are dynamic and can change rapidly in response to political, environmental, or economic events. The data analyzed in this study offers only a snapshot of engagement patterns. Longitudinal studies could provide deeper insights into how public engagement with STIs evolves over time, especially as governments and corporations introduce new policies or products.

Lastly, we focused on consumer engagement in social media posts. We did not focus on actual sales of the STI, which is the ultimate KPI measuring adoption. We also did not focus on the differential roles of NGOs, Govt, influencers, corporate communication, etc. The role of the type of organization may play a differential role in adoption. Future researchers should focus on these aspects. Future research may also extend this work by incorporating semantic complexity and explicit technical terminology as complementary dimensions of text complexity, particularly in expert-oriented or long-form communication contexts.

VII. CONCLUSION

This study significantly advances understanding of social media engagement with content related to STI. We explore the same across different economic contexts. The findings highlight the importance of text complexity, with an optimal level that enhances engagement—simpler for developing countries and more technical for developed ones. Topic analysis reveals regional variations, emphasizing short-term themes like electric vehicles in developed markets and a mix of immediate and future topics in developing ones. The role of emotions, particularly trust and fear, underscores effective communication strategies.

The contributions of this paper are threefold. First, it extends the literature on sustainable technology adoption by shifting attention from user-generated content (UGC) to organization-generated content (OGC), thereby highlighting how organizational communication actively shapes public engagement. Second, it contributes methodologically by integrating topic modeling, econometric, and machine learning approaches to reveal both linear and non-linear drivers of engagement, including the novel finding of an inverted U-shaped relationship between text complexity and engagement. Third, it adds to theory by applying psychological distance and dual-process perspectives to explain why short-term and trust-oriented content resonates differently across regions.

Practical implications for marketers include crafting region-specific messages, balancing complexity, and using emotional tones strategically. Despite these insights, limitations such as the focus on social media data and lack of cultural analysis suggest areas for future research. Expanding offline engagement and exploring cultural factors can further enrich understanding of communication dynamics related to STI.

APPENDIX

Online appendix has been submitted with the manuscript.

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