



Original research article

Fossil fuel companies' climate communication strategies: Industry messaging on renewables and natural gas

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ABSTRACT

Research shows that multinational oil and gas companies have recently made a strategic shift away from outright climate denial to more nuanced discourses of climate delay. Communication on social media is an under-analyzed part of the fossil fuel industry's strategy to delay the energy transition away from fossil fuels to a renewable future. This study examines how four companies (Shell, ExxonMobil, BP, and TotalEnergies) are communicating about the renewable transition by analyzing tweets published by their global Twitter accounts. Each of these companies tweets about different renewable technologies in the context of showcasing their own renewable projects. TotalEnergies and BP focus mostly on solar, ExxonMobil on biofuels, and Shell on hydrogen; geothermal and hydropower are hardly mentioned by any of the companies. The number of tweets mentioning renewables increased rapidly after 2015. Topic modeling on tweets about renewables shows that renewables are often mentioned together with natural gas, emphasizing how both are essential for emissions reductions. Similarly, computational text analysis on tweets about natural gas reveals how companies highlight the social good of natural gas including promoting its role in emissions reductions, presenting natural gas as a fuel for a cleaner future, and emphasizing that natural gas is critical to meeting growing societal demand for energy. This pattern of communication - linking renewables to natural gas and promoting natural gas as part of their corporate response to climate change - suggests an evolution of fossil fuel companies' strategic efforts to delay the energy transition and obstruct climate action.

1. Introduction

As the climate crisis worsens, global calls to end fossil fuel reliance, to accelerate renewable energy deployment, and to regulate the fossil fuel industry's extraction of oil and gas are growing [1,2]. Despite the fossil fuel industry's decades-long strategic investments to deny the impact that fossil fuels have on climate [3–5] and to strategically avoid the issue of climate change in their communications [6], major oil and gas companies now acknowledge environmental concerns and integrate this acknowledgement into their communication strategies [7,8]. Many of these companies have announced a variety of targets to mitigate emissions from their daily operations and from their products [8], and most major oil and gas companies have made some investment in renewables and low-carbon technology [9].

Because these companies continue to lobby against ambitious climate policy while profiting from continued fossil fuel exploration and

extraction, these seemingly positive claims and their promotion of renewables need to be examined carefully, particularly given the well-documented legacy of these companies strategic spreading of misinformation and aggressive policy interventions to slow down climate action [6,8]. Recent research also suggests that there is a strategy shift in the oil and gas industry from outright climate denial to more nuanced “discourses of delay” [8,10–12], which includes public support and endorsement of climate action but in practice doing little and strategically delaying real change. For example, a recent study by Lamb et al. (2020) identified, described, and categorized a variety of climate delay discourses, including: 1) redirect responsibility, 2) push non-transformative solutions, 3) emphasize the downsides of climate policy, and 4) surrender to climate change [10]. Research on the phenomenon of *greenwashing* [13–16], which refers to poor environmental performance coupled with positive communication about environmental performance, also shows the importance of public

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communication in corporate strategy [17]. Recent research shows that many oil and gas companies are publicly communicating about significant efforts regarding renewable deployment while their actual investments in renewables are minor [18].

A growing body of scholarship on the oil and gas industry's climate obstruction shows how the industry is shifting strategies from denying that fossil fuels are causing climate change to more recent efforts to delay actions that promote renewables and reduce fossil fuel reliance. Research on the climate actions and discourses of major oil companies over the last few decades reveals that companies' public support for a renewable energy transition is a recent shift away from previous efforts of oil and gas majors to deny climate change [6,8,19]. Since the basic idea of an energy transition requires a global move away from fossil fuels toward a more renewable-based future, it is valuable to understand whether and how fossil fuel companies are publicly engaging with the potential of renewable energy technologies to displace fossil fuels. The transformation in energy systems that is needed for climate mitigation requires not only an increase in renewable energy generation, but also a parallel reduction in fossil fuel extraction and use [2]. While the past decade has seen a rapid increase in renewable energy generation around the world [20], many fossil fuel companies, particularly large multinational fossil fuel companies, have no current plans to reduce their exploration and extraction of fossil fuel supply [2,21]. Recent research confirms that fossil fuel interests are co-opting the idea of transition to a more performative "trasformismo" which refers to the phenomenon where those in power hold onto power by forming coalitions to prevent the formation of any credible opposition [22].

Within this context, it is valuable to assess how fossil fuel organizations are behaving and adapting in the face of worsening climate change impacts [23]. In particular, improved understanding about how oil and gas companies are responding to the urgent need for an energy transition that phases out fossil fuels is important, because large oil and gas companies are often regarded both as central to climate mitigation efforts [24], and also as major contributors to global carbon emissions [25]. Scholars have examined how powerful companies strategically downplay the need for radical and transformational climate solutions and delay climate action [5–8,11,26–30]. For example, a recent study reveals how ExxonMobil uses rhetoric and framing to shape public discourse on climate change through multiple different communication outputs including publications, internal documents and advertorials published in *The New York Times* [11]. Most of the existing research on oil and gas companies' climate communication focuses on revealing the industry's strategic efforts to delay action on climate change, while there has been scarce research on how large, multinational oil and gas companies are communicating about renewables.

To date, there is no published research on the oil and gas companies public messaging on their social media accounts. Recent research on other industries (e.g., tobacco, food) points out that many companies have embraced Twitter as a mechanism to influence public perception as part of a strategy to oppose, weaken and resist policy [31,32]. In terms of oil and gas industry public messaging, relevant research identifies how Facebook advertising is being used to promote an image of a climate-friendly fossil fuel industry, including announcing voluntary targets and internal investments in renewable energy, as well as promoting natural gas as a green fuel, and reinforcing the critically important role of oil and gas in the energy mix [33]. Yet, little attention has been paid to Twitter, which has been an important social media platform with 206 million registered users and expansive power to disseminate information and influence policy debates [31,34]. Research ranging from sentiment analysis to social network analysis reveals the critical role of Twitter in influencing public opinion, shifting people's behaviors, and shaping public policy [35,36]. Twitter is a social media platform that is popular among companies for professional information sharing, marketing, and engagement [37]. Twitter messaging is, therefore, an important component of understanding how the fossil fuel industry is engaging with energy transitions, renewable energy and their corporate response

to climate change. Analyzing twitter data also contributes to filling an important methodological gap identified by Supran and Oreskes (2021) – the lack of computational methods applied to analyze how the fossil fuel industry uses certain narratives to frame public discourse to undermine climate litigation, regulation, and activism.

Recognizing these gaps, we designed a study to address our initial research question - how are fossil fuel companies communicating about renewable energy technologies on Twitter? We extracted all of the 25,233 tweets published by the global Twitter accounts of Shell, ExxonMobil, BP, and TotalEnergies and performed computational text analysis (i.e., topic modeling) on the tweets about renewable energy. As we explored this question, we found an unexpected result: renewable energy and natural gas are often mentioned together. The messaging frequently emphasizes that both renewables and natural gas are critical for emissions reductions. Based on this result, we added another research question to ask how are these companies communicating about natural gas. Topic modeling was then conducted on all the tweets that mentioned natural gas.

In the next section, we review the methods used to analyze the Twitter data. We then discuss the results of our analysis and explore insights from these results. The paper concludes with a discussion of the significance of this research, its limitations and suggestions for future research directions.

2. Methods

Computational text analysis (i.e., topic modeling) was applied to examine Twitter messages from four international oil and gas companies: Shell, ExxonMobil, BP, and TotalEnergies. These four companies were selected because of their large market capitalization, their size of direct and indirect historical greenhouse gas emissions [19], and different headquarter jurisdictions; i.e., at the time of company selection in December 2021, Shell was based in the Netherlands (i.e., Shell has since moved its headquarters to the UK), ExxonMobil in the USA, BP in the UK, and TotalEnergies in France.

The methodological procedure included a series of steps (summarized in Fig. 1): 1) data extraction through Twitter API V2 for academic research, 2) a search of renewable energy tweets (*Search terms*: solar – wind – hydro – bio – geothermal), 3) data cleaning to include only tweets about renewable energy, 4) text preprocessing and topic modeling on renewable energy tweets, 5) a search of natural gas tweets (*Search terms*: natural gas – LNG – LPG – CNG), 6) data cleaning to include only tweets about natural gas, 7) text preprocessing and topic modeling on natural gas tweets, and 8) creation of a timeline of the number of renewable energy tweets and natural gas tweets. All analyses were conducted in Python.

As a first step, the data were extracted using Twitter API V2 for academic research on January 29, 2022, including 25,233 longitudinal tweets published by their global Twitter accounts from 2009 to 2021. Data included the very first tweets each company posted starting as early as 2009 through to those posted at the end of 2021. Only English language tweets were extracted, and we did not include tweets that were replies to another tweet.

After data extraction, we used specific keywords to filter tweets about renewables and natural gas. Our research was initially intended to examine tweets that mention major renewable energy technologies, including solar energy, wind energy, bioenergy, renewable hydrogen, geothermal, and hydropower. Search terms included solar, wind, hydro, bio, and geothermal (i.e., the term "bio" captured bioenergy, biofuels and biopower and "hydro" captured tweets about renewable hydrogen, hydropower, and hydroelectric energy). Search terms for natural gas included natural gas, LNG (i.e., liquefied natural gas), LPG (i.e., propane liquefied under modest pressure in cylinders), and CNG (i.e., compressed natural gas). Searches were case-insensitive.

After data extraction, data cleaning was conducted manually for both subsamples: the renewable energy tweets and the natural gas tweets.

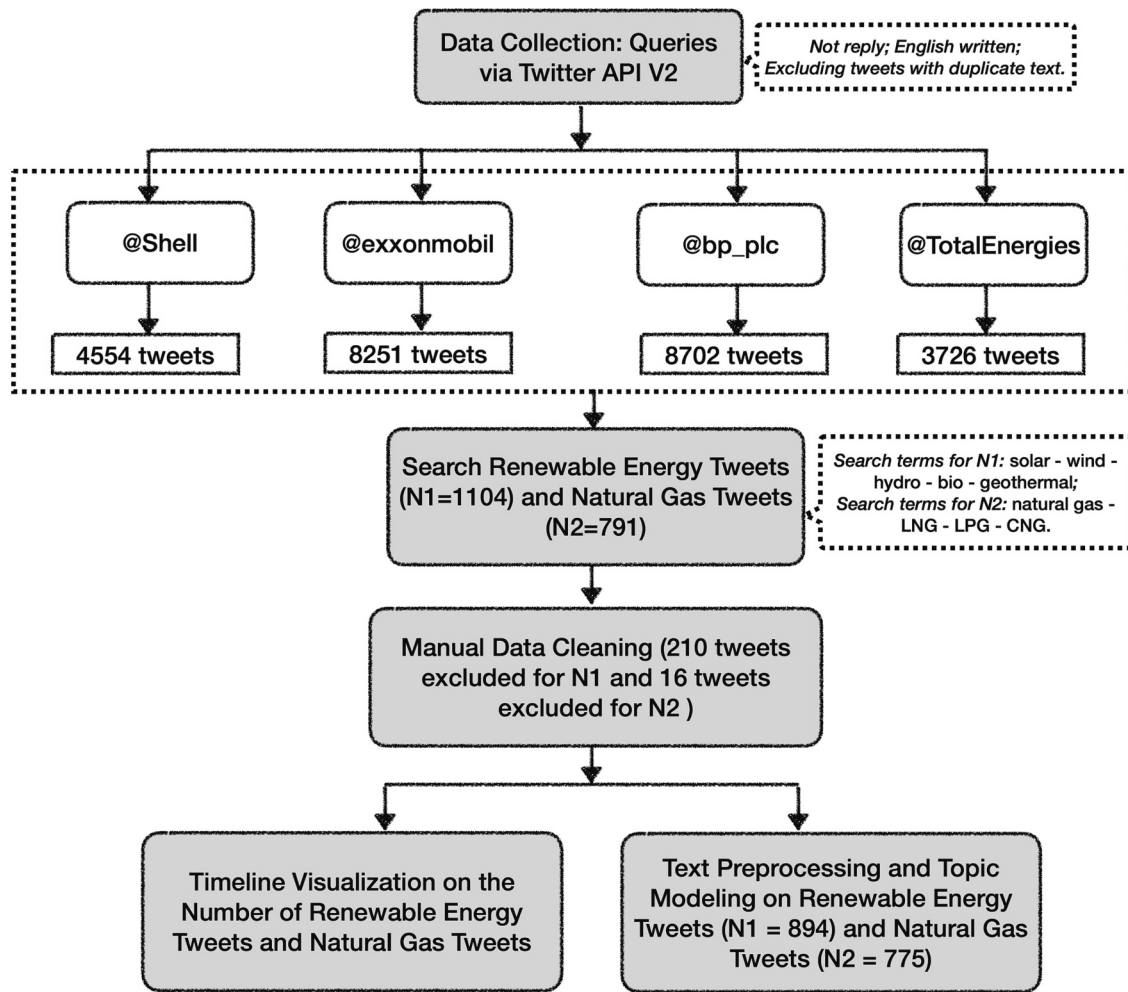


Fig. 1. Methodological procedure.

The data cleaning process removed irrelevant tweets that were not about renewables or natural gas. For example, tweets containing the word “windows” which were initially included from the search term of “wind” were removed before data analysis. After data cleaning, there were 894 tweets in the first subsample related to renewables and 775 tweets related to natural gas. With the dates of each tweet, we created a timeline of renewable energy tweets and natural gas tweets.

To analyze the refined dataset, we performed topic modeling, which is an unsupervised machine learning approach to conduct text analysis, focusing on discovering embedded latent structure from large text corpora [38]. In topic modeling, a document is considered a collection of words containing multiple topics in different proportions [38]. Among the variety of methods for topic modeling, Latent Dirichlet Allocation (LDA) is the most popular [39], assuming that documents are constructed from multiple topics and that each individual word can be used in a variety of ways [40]. In this context, a document is a tweet. A tweet may be largely about carbon emissions, while also being about renewable energy projects and company leadership (e.g., 60 % carbon emissions, 20 % renewable energy project, and 20 % company leadership). Although LDA is typically used on longer documents rather than individual tweets, research shows that the performance of topic models produced by LDA on Twitter data is significantly improved when tweets

are aggregated or pooled together by some common factors [41,42]. For our analysis, we extracted and pooled the tweets from all four fossil fuel companies, and the two subsamples are about renewable energy or natural gas respectively.

Before any topic modeling can be done, each tweet needs to be adjusted to a format that will facilitate discrete topics [41] with the use of text preprocessing. Text preprocessing involves lowercasing all letters, removing punctuation, stop words, URLs, usernames, and unnecessary characters to ensure that only essential information is included in the dataset for topic modeling.

In addition to these multiple preprocessing choices that are made by the researchers before analysis, topic modeling also requires the researcher to make a number of qualitative decisions. There is no objective way to determine the single best model for a text, and the “objective” methods that have been proposed are often not the most substantively helpful [40]. While there are some mathematical approaches to determining the number of topics, for social scientists, who are typically motivated by a particular substantive research question, the best way to determine the number of topics is by the usefulness of the output [40]. In addition, as DiMaggio et al. argued, there is no statistical test for the optimal number of topics or for the quality of a solution when topic modeling is used to identify themes and assist in interpretation

Table 1

Descriptive summary of the Twitter dataset.

Company	Country	Twitter username	Joined	Number of tweets	Renewable energy tweets	Natural gas tweets
Shell	Netherlands	@Shell	February 2009	4,554	222	228
ExxonMobil	USA	@exxonmobil	April 2009	8,251	221	301
BP	UK	@bp_plc	August 2013	8,702	231	106
TotalEnergies	France	@TotalEnergies	October 2009	3,726	220	140

Note: Country information is based on their headquarters in 2021.

Table 2

Comparison of mentions of renewable energy technologies.

Company	Solar	Wind	Hydrogen	Biofuels	Geothermal	Hydropower
Shell	71	35	89	40	1	4
ExxonMobil	11	23	10	181	1	1
BP	87	70	22	64	2	1
TotalEnergies	147	27	20	39	0	2

Note: One tweet might contain two or more renewable energy technologies so the total number of renewable energy tweets here might exceed the total number in Table 1.

rather than to predict a knowable state or quantity [43]. Indeed, a statistical test for an overall solution would be misleading, because models often shunt noisy data into uninterpretable topics in ways that strengthen the coherence of topics that remain [43]. Therefore, in our research, topic modeling was conducted on both renewable energy tweets and natural gas tweets, and the number of topics was determined with a qualitative approach for both subsamples. Different numbers of topics were tested (from 2 to 12), and the quality of the inferred topics was compared to determine the optimal number of topics. To facilitate the qualitative interpretation, we also utilized interactive visualization through pyLDAvis, a web-based package/tool to help interpret and evaluate the topics by viewing the topics-keywords distribution, the prevalence of each topic, and relevance between each topic.

By fitting tweets into the LDA models, it is possible to create a list of weighted words, which indicate the subject of each topic, and a weight distribution across topics for each document [44]. Since topic modeling could cluster words that tend to co-occur into the same topic, all identified top words in each of the topics can be linked together to understand various communication patterns and strategies that have been employed in certain messages. As Jacobs and Tschötschel noted, topics representing a collection of themes can be interpreted as a collection of patterns of language use, each pattern featuring in a topic [38]. For example, in our case, all the patterns that emerged in the subsample of renewable energy tweets can be interpreted as being related to renewable energy technologies since the subsample is thematically about renewables.

3. Results

The dataset included a total of 25,233 tweets across all four companies from 2009 until 2021. Our initial queries resulted in 4,655 tweets from Shell, 8,797 tweets from ExxonMobil, 8,729 tweets from BP, and 3,986 tweets from TotalEnergies. Once tweets with duplicate text were deleted, the dataset was reduced to 4,554 tweets for Shell, 8,251 for ExxonMobil, 8,702 for BP, and 3,726 for TotalEnergies, resulting in the total of 25,233 tweets in all. The earliest tweet in the dataset was from

Shell in February 2009, and the dataset included all tweets through the end of 2021. Although BP joined Twitter last in August 2013, BP has the largest overall volume of tweets compared to the other three companies.

The initial keyword search focusing on renewable energy technologies returned 1,104 tweets, which was reduced to 894 after data cleaning, thereby excluding 210 tweets that were not explicitly about renewable energy technologies. Similarly, an initial keyword search focusing on natural gas returned 791 tweets. After manual data cleaning, 16 tweets were excluded resulting in 775 tweets about natural gas that were analyzed (228 tweets about natural gas from Shell, 301 from ExxonMobil, 106 from BP, and 140 from TotalEnergies). A descriptive summary of the Twitter data is shown in Table 1.

3.1. Mentions of renewable energy technologies

All four companies have some public mentions of solar, wind, hydrogen, biofuels and hydropower. With regard to tweets about solar power, TotalEnergies tweets the most about solar while ExxonMobil tweets the least about it. ExxonMobil tweets the most about biofuels, BP tweets the most about wind, and Shell tweets the most about hydrogen. Geothermal energy is only mentioned by BP twice, by Shell and ExxonMobil once and never mentioned by TotalEnergies. Hydropower is mentioned at least once by each company but infrequently overall. A comparison of all the tweets about renewable energy technologies across the four companies is shown in Table 2. By examining renewable energy tweets within each company, TotalEnergies and BP focus mostly on solar, ExxonMobil focuses mostly on biofuels, and Shell on hydrogen.

3.2. Temporal distribution of tweets

A timeline of the annual and cumulative count of tweets published about renewable energy and natural gas by all four companies (Fig. 2) shows that there is an increase in renewable energy tweets post-2015, which may reflect increased pressure on fossil fuel companies after the 2015 UNFCCC Paris climate accord. Tweets about natural gas peak in 2017 and then decline.

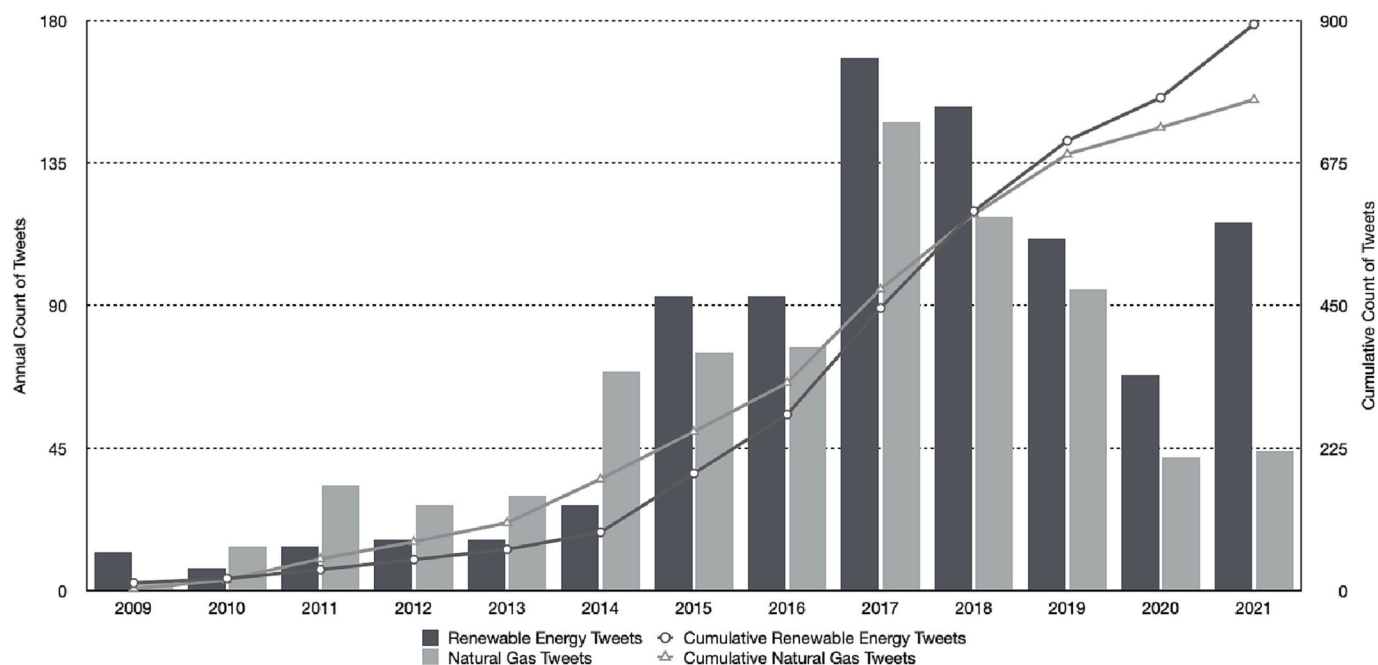


Fig. 2. Timeline of annual (bar graph) and cumulative (line graph) renewable energy tweets and natural gas tweets from Shell, ExxonMobil, BP, and TotalEnergies.

3.3. Topics of renewable energy tweets

The objective of topic modeling was to identify the most central topics associated with messaging in the tweets mentioning renewable energy. Top words in each of the identified topics provide insights on the communication strategies that the oil and gas companies have been using to publicly discuss renewable energy.

Results of topic modeling reveal six topics within the renewable energy tweets: solar energy projects, the role of hydrogen in lowering emissions, wind energy projects, the potential of algae as a biofuel, natural gas as a fuel for emissions reductions, and biofuel business. Based on the descriptive statistics of topic distribution (similar to the approach used by Si [45]; can be found in the Supplementary Material), each of these topics is captured and represented in the tweets from the four companies. Based on the list of top words that tend to co-occur into the same topic and a weighted distribution across topics for each tweet, Table 3 presents the details of topic label, topic prevalence,

characteristic words from the top 30 salient words, representative tweets (based on weighted distribution), and source and date. In topic modeling, a document is considered as a collection of words containing multiple topics with different proportions, and the weight represents the percentage of a specific topic for a document. For example, if the weight of Topic 1 for a tweet is 0.92, the tweet is 92 % about Topic 1 and can be considered as a representative tweet for Topic 1. In Table 3, we present a representative tweet for each of the topics. Since all the tweets in this subsample are about renewables, it is not surprising to find that most topics have specific top words related to specific renewable energy technologies, as shown in Table 3. The visualizations of each of the six topics, using the pyLDAvis tool, can be found in the Supplementary Material.

Solar energy projects (23.3 % of tokens, Topic 4) emerged as the most prevalent topic, suggesting that solar is the renewable technology that dominates renewable energy messaging in these tweets. The second most prevalent topic focuses on the role of hydrogen fuel (19.2 % of

Table 3

Six topics identified within renewable energy tweets (sorted by topic prevalence).

Topic label and topic ID	Topic prevalence	Characteristic words among top 30 most relevant terms	Representative tweet	Source and date
Solar energy projects (Topic 4)	23.3 %	Solar, power, energy, projects, electricity, homes	"400-acre solar farm that could power 7,500 homes. See how @SiliconRanchCo a Shell investment, is using solar power to energise communities across the USA."	Shell, 2020-01-14
The role of hydrogen in lowering emissions (Topic 5)	19.2 %	Hydrogen, carbon, low, help, energy, emissions	"Hydrogen could play a big role in lowering global emissions, by decarbonizing energy-intensive industries that are hard or expensive to electrify – like heavy transport. Take a closer look at how hydrogen can be used on the path to net zero."	BP, 2021-05-24
Wind energy projects (Topic 2)	17.8 %	Wind, project, energy, offshore, turbines, farm	"@Total is pushing forward in the emerging sector of floating offshore wind with its ambition to develop renewable energy sources, key in achieving #NetZero2050. Eolmed will be our 1st floating wind project in France together with Group Qair."	TotalEnergies, 2020-10-07
The potential of algae as a biofuel (Topic 3)	17.7 %	Biofuel, algae, research, potential, working, produce	"Happy #firstdayofspring from La Jolla, CA, where we are working with @SynGenomeInc to research algae as a potential biofuel of the future."	ExxonMobil, 2017-03-20
Natural gas as a fuel for emissions reductions (Topic 1)	12.5 %	Gas, fuel, technologies, natural, greenhouse, emissions	"Natural gas, wind and solar will be critical for meeting future energy demand and reducing CO2 emissions. #WEForesight"	Shell, 2015-01-21
Biofuel business (Topic 6)	9.5 %	Biofuels, business, green, future, algae, partnership	"It's tiny, green and wet. Could algae be the future of biofuels?"	ExxonMobil, 2017-10-09

Note: Representative tweets have been slightly adapted. We removed some redundant symbols, emojis, and hyperlinks.

tokens, Topic 5). The third most prevalent topic is about wind energy projects (17.8 % of tokens, Topic 2). Both the fourth most prevalent topic (17.7 % of tokens, Topic 3) and the least prevalent topic (9.5 % of tokens, Topic 6) are about bioenergy, with Topic 3 highlighting the potential of algae and Topic 6 highlighting the companies' biofuel businesses.

Unexpectedly, a topic focusing on natural gas (12.5 % of tokens, Topic 1) emerged as one of the main topics in the companies' renewable energy tweets. The representative tweet from Shell in Table 3 shows how natural gas is portrayed as a key fuel of the future alongside wind and solar, and how natural gas can contribute to meeting future energy demand and reducing greenhouse gas emissions. Shell mentions natural gas, solar, and wind together framing natural gas alongside these other options.

3.4. Topics of natural gas tweets

The unexpected finding that natural gas is frequently mentioned together with renewables suggests that renewable messaging plays a role in rationalizing the development of natural gas and perpetuating fossil fuel reliance by the industry. This result motivated us to perform topic modeling on natural gas tweets as well to better understand how the companies were framing their communication about natural gas. Similar to the analysis on renewable energy tweets, top words in each of the identified topics and representative tweets help us understand how natural gas is framed in the companies' public messaging. Six topics emerged, and like the renewable energy tweets, the descriptive statistics of topic distribution (see the Supplementary Material) reveal that all the topics are captured and represented in each of the four companies. Three of the six topics focus explicitly on LNG development, progress and projects, while the other three topics represent the role of natural gas in emissions reduction, natural gas as a fuel for a cleaner future, and the role of natural gas in meeting growing societal demand for energy.

Table 4 shows that the most prevalent topic (30.1 % of tokens, Topic 3) highlights the role of natural gas in emissions reduction. The second most prevalent topic (23.7 % of tokens, Topic 1) focuses on natural gas as a fuel for a cleaner future. The representative tweet from ExxonMobil shows how natural gas is portrayed as an abundant and versatile energy source that can shape a cleaner world. Another topic (12.3 % of tokens, Topic 5) highlights the role of natural gas in meeting growing societal demand for energy. Other topics focused on LNG progress (14 % of tokens, Topic 4), LNG development (12.1 % of tokens, Topic 2), and LNG projects (7.8 % of tokens, Topic 6).

Table 4
Six topics identified within natural gas tweets (sorted by topic prevalence).

Topic label and topic ID	Topic prevalence	Characteristic words among top 30 most relevant terms	Representative tweet	Source and date
The role of natural gas in emissions reduction (Topic 3)	30.1 %	Gas, natural, power, emissions, reduce, plants	"The use of gas in transportation is another way to reduce CO2 emissions, especially by blending biogas and natural gas. This is why TotalEnergies is committed to producing more "green" gas by 2030."	TotalEnergies, 2021-06-30
Natural gas as a fuel for a cleaner future (Topic 1)	23.7 %	Gas, energy, natural, future, cleaner, fuel	"We're a leading producer of natural gas, an abundant and versatile energy source. See how it's helping to shape a cleaner world around us."	ExxonMobil, 2021-06-25
LNG progress (Topic 4)	14 %	Natural, liquefied, learn, gas, largest, lng	"Next stop #Australia! Powerful tugboats are pulling a floating liquefied natural gas facility from South Korea."	Shell, 2017-07-03
Growing LNG demand (Topic 5)	12.3 %	Demand, global, lng, growth, meet, growing	"Growing #LNG demand. Record #LNG supply growth; investment. Coal-to-gas switching can help improve air quality. More in the Shell LNG Outlook 2020."	Shell, 2020-02-20
LNG development (Topic 2)	12.1 %	Lng, new, development, help, fuel, gas	"More investment in supply and new projects is needed to avoid shortage of #LNG by mid-2020s. See more in Shell LNG Outlook 2019."	Shell, 2019-02-25
LNG projects (Topic 6)	7.8 %	Project, million, production, lng, learn, floating	"@Total announces the closing of the acquisition of Anadarko's 26.5 % working interest in the Mozambique LNG project. A project that Total will now operate. Capacity of 12.9 million tonnes per year 86 % of the production is already sold."	TotalEnergies, 2019-09-30

Note: Representative tweets have been slightly adapted. We removed some redundant symbols, emojis, and hyperlinks.

4. Discussion

4.1. Different approaches to renewable energy

This analysis shows how fossil fuel companies use twitter to showcase their renewable energy projects in their fossil fuel production facilities to present themselves as engaged responsible actors in the energy transition.

Each of the four companies mentioned different renewable energy technologies reflecting their individual corporate strategy showcasing how they are investing in renewables so far. Solar is the renewable technology that dominates the public messaging on renewable energy among these four companies. Solar energy projects emerged as the most prevalent topic in their renewable energy tweets, and two of the four companies (TotalEnergies and BP) mentioned solar more than any other renewable technology (Table 2). The focus on solar energy among TotalEnergies reflects its corporate strategy of communicating about its solar energy development as one of its major energy strategies [46]. TotalEnergies uses Twitter to promote its multiple solar projects in Japan, Spain, and other places [46]. Over the past decade, TotalEnergies has made multiple strategic investments in solar, including \$1.4bn spent on acquiring a 60 % stake in the US solar firm SunPower in 2011 [47]. According to their annual report and other public communication, TotalEnergies aims to become a globally integrated leader in solar power.

BP was the first oil company to commit capital to renewable energy projects such as solar and wind, beginning as early as 1980 [47]. In 2002 BP took the bold step of rebranding itself as an energy company rather than a fossil fuel company. The company officially changed its name from "British Petroleum" to just the letters "BP" telling the world that the letters would now represent the company's mission to move "beyond petroleum" [48]. Within the next decade, this strategy faded as the company dealt with several devastating oil leaks and they returned to focusing on their core business, selling off much of their solar and wind assets [48]. In 2020, BP recommitted to growing their low carbon business [48]; this commitment beyond oil and gas is reflected in this analysis. BP tweets about solar and wind more than other renewable energy technologies. In addition, compared to the other three oil and gas companies in our analysis, BP advances wind energy in its communication more. BP currently has more than 2,200 megawatts (MW) of wind capacity in the US and has started to re-invest in renewables in recent years [47].

Shell is the company with the most mentions of hydrogen across the four companies. This is consistent with its commitment, as noted on its official website, to be a leading player in the global hydrogen market [49]. Shell advocates for hydrogen as an increasingly appealing option

for the transport sector and sees opportunities across the hydrogen supply chain. ExxonMobil is the company that mentions biofuel the most, and it is the company with the least mentions of solar, wind, and hydrogen. Its focus on biofuels is consistent with its company strategy around advancing biofuels [47].

4.2. Communicating renewables to strategically justify natural gas

The unexpected result of the topic modeling, that natural gas is often mentioned in conjunction with renewables, reinforces the idea that these companies are strategically mentioning renewable technologies as a way to reinforce the future of their core business, oil and gas. The tweets that simultaneously mention both renewables and natural gas are perpetuating the notion that both are necessary; that although renewables have promise for the future - natural gas, the cleanest of all fossil fuels - has a critically important role to play now and in the future.

Although the technology focus represented by each of the four companies in their tweets is largely consistent with what the companies are communicating elsewhere (e.g., such as on their official website), our analysis focuses only on what the companies are communicating – not what they are actually doing. Additional analysis could explore in more depth the consistency in representation of what they are actually doing. Li et al. (2022) found a mismatch between oil and gas companies' discourse, pledges, actions and investments and concluded that none of the large oil and gas companies is currently on the way to a clean energy transition [8]. Employee resignations from large fossil fuel companies have recently been reported in the media. For example, a senior safety consultant recently quit working with Shell after 11 years, accusing the fossil fuel producer of causing “extreme harms” to the environment [50]. This demonstrates growing concern about the integrity of these companies in terms of what they are communicating and what they are doing. The sharp increase in communication about renewable energy in 2015 (Fig. 2) may not necessarily represent a sharp increase in renewable energy investment. This is the climate delay strategy that Lamb et al. called “all talk, little action”, which fits in the category of pushing non-transformative solutions within climate delay discourses [10].

4.3. Industry communication strategies identified through natural gas messaging

Our analysis of natural gas messaging also demonstrates how these companies present their fossil fuel extraction as a social good. The most prevalent topic of the natural gas tweets focuses on the role of natural gas in emissions reductions. This framing, which positions natural gas as equivalent to the recognized benefits of renewable energy technologies, serves to reinforce continued fossil fuel reliance and hinder transformational energy system change.

The results of our analysis align with previous research on how fossil fuel hegemony is reproduced by linking local and specific benefits to nationally or globally recognized interests such as employment, energy security and emission reductions [29]. This was also highlighted by Wright et al. [5] who found that oil and gas companies have emphasized assumed common interests between the industry, government and citizens as forms of propaganda.

The second most prevalent topic (emerged from natural gas tweets), representing natural gas as a fuel for a cleaner future, shows how natural gas is being promoted as part of the corporate response to climate change. Of all fossil fuels, natural gas emits the lowest amount of carbon dioxide per unit of energy when it is burned, so it is technically a cleaner fuel than coal or oil. Natural gas is still, however, classified as a polluting fossil fuel (by the U.S. Energy Information Administration). Research also shows that the climate impacts of natural gas are underestimated and that promoting natural gas hinders transformational climate action [51]. Our analysis confirms the complexity of how natural gas is positioned in the energy transition by different constituents. When policy-makers and companies refer to a “low-carbon economy”, they are

recognizing that there will be some carbon, but it should be as low as possible. Similarly, the tweets from the oil and gas industry refer to natural gas using the phrase “cleaner fuel” not “clean fuel”. These are subtle but strategic distinctions that perpetuate nebulous or simplistic understanding among the general public about the risks and benefits of fossil fuels.

The third relevant topic reflecting corporate communication strategy is about “growing LNG demand”, which redirects responsibility from fossil fuel extraction to consumers. This is similar to what Supran and Oreskes observed - ExxonMobil's advertorials disproportionately employ terms that present consumer demand for energy, rather than corporate supply of oil, coal, and gas, as the cause of fossil fuel production [11].

4.4. Corporate strategy shift, discourses of climate delay, and hegemonic power

Promoting natural gas as beneficial for the energy transition reinforces carbon lock-in, which contributes to delaying the energy transition to renewables [21,51]. Research shows that companies such as BP and Shell have a history of using a range of discursive narratives that evade their own responsibility for climate change, and instead focus attention on their ability to use technologies to reduce emissions, their reliability as energy providers, and their willingness to be partners in the transition [52]. Our research uses Twitter data and novel methods to reveal various communication strategies employed by those large oil and gas companies to portray an image of being environmentally friendly while perpetuating fossil fuel reliance. It echoes previous research on how the oil and gas industry accepts the existence of climate change but justifies inaction or inadequate efforts [8].

Despite the corporate strategy shift away from outright climate denial to more nuanced discourses of climate delay, recent research continues to suggest that hegemonic power is central to the fossil fuel industry's regime of climate obstruction [53]. Multiple scholars have drawn from Gramsci's [54] notion of hegemony which involves attempts to ensure that the interests and identities of dominant groups are identified with, or overlap with, the interests of others in society [55] and discussed fossil fuel hegemony to explain how powerful companies strategically maintain a dominant ideology that downplays the need for radical and transformational climate solutions and delays climate action [5,26–29]. For example, Wright et al. identified the key discourses that the Australian fossil fuel sector has employed in reproducing hegemony and delaying action on climate change, revealing how the fossil fuel sector continues to avoid social and political sanction given the threat its activities pose to the future of human civilization [5]. The communication approach we found in both renewable energy tweets and natural gas tweets serves several functions in constructing hegemony. Our analysis adds to this line of research by revealing how the fossil fuel industry is strategically communicating about renewables to delay the energy transition and obstruct action on climate change.

5. Conclusions

It is widely recognized that fossil fuel companies, particularly large multinational oil and gas companies, continue to have a strong influence on climate policy and are slowing down the transition toward a renewable future. Prior to this study, analysis on how these companies leverage their power through social media platforms was limited. Applying computational text analysis, this study contributes to a deeper understanding of how fossil fuel companies are communicating about the renewable transition. The communication approach linking renewables to natural gas and promoting natural gas as part of their corporate response to climate change, suggests an evolution of corporate strategic efforts to delay the energy transition and obstruct climate action.

Our research makes three key contributions. First, this analysis adds to organizational research by illustrating how large oil and gas

companies are using communication strategies about renewable energy to delay the energy transition and obstruct action on climate change. Our study uses social media data and adds to the literature on strategic corporate messaging on sustainability, climate and energy as well as corporate engagement, with transition and transformations as part of a delay tactic. Second, our research sheds light on how computational methods such as topic modeling can offer insights on identifying certain narratives used by the oil and gas industry to frame public discourse to undermine climate litigation, regulation, and activism. Topic modeling has allowed us to identify the communication approach in a more rigorous way, thus advancing in areas where traditional text analysis has struggled, such as scaling, repetition, and systematization. Finally, our research has valuable policy implications. It raises the need for additional assessment of the oil and gas industry's global online communication activities and for further external pressure to facilitate transformational change.

Several limitations of our study suggest future research directions. First, global Twitter accounts of oil and gas companies are only one piece of the fossil fuel industry's communication strategy and their social media ecosystem. Future research could comparatively assess communication from other companies and on other platforms such as Facebook or Instagram. Future research could also look more holistically at corporate communication including paid advertisements beyond social media. Non-English tweets could also be examined. Second, we have not comprehensively explored whether the information on Twitter is consistent with the actions of the companies. Future research could analyze more specifically alignment between their public statements and their actions. Third, our research examined only renewable energy tweets and natural gas tweets. Future research could explore oil and gas companies' statements on climate change and social and ecological issues on Twitter. Fourth, this study did not explore the connections the companies have on their social media platforms; i.e., we did not conduct social network analysis to assess which organizations are linked, whether and how different companies are reacting to each other, or retweeting each other's messaging, nor did we assess which partnerships are being highlighted on each social media platform. Such analyses could provide a broader picture across the fossil fuel industry as a whole. We also recognize that recent corporate changes within Twitter itself are reducing the scale and scope of the influence of this particular social media platform.

As pressure is mounting to phase out fossil fuel supply [2], and the movement toward a global fossil fuel non-proliferation treaty is growing [56], business as usual for oil and gas companies is becoming more difficult. Presenting themselves as engaged renewable energy promoters through their public messaging provides another mechanism to delay more impactful regulatory measures that could restrict fossil fuel supply, end fossil fuel exploration, and lead to larger transformative changes in the fossil fuel industry.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary Materials

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.erss.2023.103028>.

References

- [1] IPCC, Climate Change 2022: Impacts, Adaptation and Vulnerability, Accessed: May 31, 2022. [Online]. Available: 2022 <https://www.ipcc.ch/report/ar6/wg2/>.
- [2] P. Newell, A. Simms, Towards a fossil fuel non-proliferation treaty, *Clim. Policy* 20 (8) (2020) 1043–1054, <https://doi.org/10.1080/14693062.2019.1636759>.
- [3] P.C. Frumhoff, R. Heede, N. Oreskes, The climate responsibilities of industrial carbon producers, *Clim. Chang.* 132 (2) (2015) 157–171, <https://doi.org/10.1007/s10584-015-1472-5>.
- [4] N. Oreskes, E.M. Conway, *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*, Bloomsbury Publishing, USA, 2011.
- [5] C. Wright, D. Nyberg, V. Bowden, Beyond the discourse of denial: the reproduction of fossil fuel hegemony in Australia, *Energy Res. Soc. Sci.* 77 (2021), 102094, <https://doi.org/10.1016/j.erss.2021.102094>.
- [6] G. Supran, N. Oreskes, Assessing ExxonMobil's climate change communications (1977–2014), *Environ. Res. Lett.* 12 (8) (2017), 084019, <https://doi.org/10.1088/1748-9326/aa815f>.
- [7] C. Bonneuil, P.-L. Choquet, B. Franta, Early warnings and emerging accountability: total's responses to global warming, 1971–2021, *Glob. Environ. Change* 71 (2021), 102386, <https://doi.org/10.1016/j.gloenvcha.2021.102386>.
- [8] M. Li, G. Trencher, J. Asuka, The clean energy claims of BP, Chevron, ExxonMobil and Shell: a mismatch between discourse, actions and investments, *PLoS ONE* 17 (2) (2022), e0263596, <https://doi.org/10.1371/journal.pone.0263596>.
- [9] H. Breetz, M. Mildenberger, L. Stokes, The political logics of clean energy transitions, *Bus. Polit.* 20 (4) (2018) 492–522, <https://doi.org/10.1017/bap.2018.14>.
- [10] W.F. Lamb, et al., Discourses of climate delay, *Glob. Sustain.* 3 (2020), e17, <https://doi.org/10.1017/sus.2020.13>.
- [11] G. Supran, N. Oreskes, Rhetoric and frame analysis of ExxonMobil's climate change communications, *One Earth* 4 (5) (2021) 696–719, <https://doi.org/10.1016/j.oneear.2021.04.014>.
- [12] A. Pringle, D. Robbins, From denial to delay: climate change discourses in Ireland, *Administration* 70 (3) (2022) 59–84, <https://doi.org/10.2478/admin-2022-0019>.
- [13] S.V. de Freitas Netto, M.F.F. Sobral, A.R.B. Ribeiro, G.R.da L. Soares, Concepts and forms of greenwashing: a systematic review, *Environ. Sci. Eur.* 32 (1) (2020) 19, <https://doi.org/10.1186/s12302-020-0300-3>.
- [14] S.J. Scanlan, Framing fracking: scale-shifting and greenwashing risk in the oil and gas industry, *Local Environ.* 22 (11) (2017) 1311–1337, <https://doi.org/10.1080/13549839.2017.1345877>.
- [15] K. Nishitani, T.B.H. Nguyen, T.Q. Trinh, Q. Wu, K. Kokubu, Are corporate environmental activities to meet sustainable development goals (SDGs) simply greenwashing? An empirical study of environmental management control systems in vietnamese companies from the stakeholder management perspective, *J. Environ. Manag.* 296 (2021), 113364, <https://doi.org/10.1016/j.jenvman.2021.113364>.
- [16] M.C. Abraham-Dukuma, Dirty to clean energy: exploring 'oil and gas majors transitioning', *Extr. Ind. Soc.* 8 (3) (2021), 100936 <https://doi.org/10.1016/j.exis.2021.100936>.
- [17] M.A. Delmas, V.C. Burbano, The drivers of greenwashing, *Calif. Manag. Rev.* 54 (1) (2011) 64–87, <https://doi.org/10.1525/cmr.2011.54.1.64>.
- [18] H. Grove, M. Clouse, Renewable energy commitments versus greenwashing: board responsibilities, *Corp. Ownersh. Control* 18 (3) (2021) 423–437, <https://doi.org/10.22495/cocv18i3siart15>, special issue.
- [19] D. Kenner, R. Heede, White knights, or horsemen of the apocalypse? Prospects for big oil to align emissions with a 1.5 °C pathway, *Energy Res. Soc. Sci.* 79 (2021), 102049, <https://doi.org/10.1016/j.erss.2021.102049>.
- [20] H. Ritchie, M. Roser, P. Rosado, Energy, Accessed: Dec. 06, 2022. [Online]. Available: in: Our World Data, 2022 <https://ourworldindata.org/renewable-energy>.
- [21] R. York, S.E. Bell, Energy transitions or additions?: why a transition from fossil fuels requires more than the growth of renewable energy, *Energy Res. Soc. Sci.* 51 (2019) 40–43, <https://doi.org/10.1016/j.erss.2019.01.008>.
- [22] P. Newell, Transformismo or transformation? The global political economy of energy transitions, *Rev. Int. Polit. Econ.* 26 (1) (2019) 25–48, <https://doi.org/10.1080/09692290.2018.1511448>.
- [23] B.K. Sovacool, et al., Sociotechnical agendas: reviewing future directions for energy and climate research, *Energy Res. Soc. Sci.* 70 (2020), 101617, <https://doi.org/10.1016/j.erss.2020.101617>.
- [24] N. Stern, *The Economics of Climate Change: The Stern Review*, Cambridge University Press, Cambridge, 2007, <https://doi.org/10.1017/CBO9780511817434>.
- [25] IEA, World Energy Outlook 2012 – Analysis, Accessed: Oct. 28, 2022. [Online]. Available: 2012 <https://www.iea.org/reports/world-energy-outlook-2012>.

- [26] G. Ferns, K. Amaeshi, Fueling climate (In)Action: how organizations engage in hegemonization to avoid transformational action on climate change, *Organ. Stud.* 42 (7) (2021) 1005–1029, <https://doi.org/10.1177/0170840619855744>.
- [27] M. Megura, R. Gunderson, Better poison is the cure? Critically examining fossil fuel companies, climate change framing, and corporate sustainability reports, *Energy Res. Soc. Sci.* 85 (2022), 102388, <https://doi.org/10.1016/j.erss.2021.102388>.
- [28] D.L. Levy, D. Egan, A neo-gramscian approach to corporate political strategy: conflict and accommodation in the climate change negotiations*, *J. Manag. Stud.* 40 (4) (2003) 803–829, <https://doi.org/10.1111/1467-6486.00361>.
- [29] D. Nyberg, C. Wright, J. Kirk, Dash for gas: climate change, hegemony and the scalar politics of fracking in the UK, *Br. J. Manag.* 29 (2) (2018) 235–251, <https://doi.org/10.1111/1467-8551.12291>.
- [30] J.P. Tilsted, A. Mah, T.D. Nielsen, G. Finkill, F. Bauer, Petrochemical transition narratives: selling fossil fuel solutions in a decarbonizing world, *Energy Res. Soc. Sci.* 94 (2022), 102880, <https://doi.org/10.1016/j.erss.2022.102880>.
- [31] C. Watts, M. Heffler, B. Freeman, 'We have a rich heritage and we believe, a bright future': how transnational tobacco companies are using twitter to oppose policy and shape their public identity, *Tob. Control.* 28 (2) (2019) 227–232, <https://doi.org/10.1136/tobaccocontrol-2017-054188>.
- [32] D. Hunt, How food companies use social media to influence policy debates: a framework of Australian ultra-processed food industry twitter data, *Public Health Nutr.* 24 (10) (2021) 3124–3135, <https://doi.org/10.1017/S1368980020003353>.
- [33] InfluenceMap, Climate Change and Digital Advertising - The Oil & Gas Industry's Digital Advertising Strategy, 2021. <https://influencemap.org/report/Climate-Change-and-Digital-Advertising-a40c8116160668aa2d865da2f5abe91b>.
- [34] Statista Research Department, Twitter: Most Users by Country, 2022. <https://www.statista.com/statistics/242606/number-of-active-twitter-users-in-selected-countries/>.
- [35] X. Liu, A.C. Burns, Y. Hou, An investigation of brand-related user-generated content on twitter, *J. Advert.* 46 (2) (2017) 236–247, <https://doi.org/10.1080/00913367.2017.1297273>.
- [36] B.J. Jansen, M. Zhang, K. Sobel, A. Chowdury, Twitter power: tweets as electronic word of mouth, *J. Am. Soc. Inf. Sci. Technol.* 60 (11) (2009) 2169–2188, <https://doi.org/10.1002/asi.21149>.
- [37] B.(Kevin) Chae, Insights from hashtag #supplychain and Twitter Analytics: Considering Twitter and Twitter data for supply chain practice and research, *Int. J. Prod. Econ.* 165 (2015) 247–259, <https://doi.org/10.1016/j.ijpe.2014.12.037>.
- [38] B.(Kevin) Chae, Corporate social responsibility (CSR): a survey of topics and trends using Twitter data and topic modeling, *Sustainability* 10 (7) (2018) 7, <https://doi.org/10.3390/su10072231>.
- [39] H. Jelodar, et al., Latent dirichlet allocation (LDA) and topic modeling: models, applications, a survey, *Multimed. Tools Appl.* 78 (11) (2019) 15169–15211, <https://doi.org/10.1007/s11042-018-6894-4>.
- [40] L.K. Nelson, Computational grounded theory: a methodological framework, *Sociol. Methods Res.* 49 (1) (2020) 3–42, <https://doi.org/10.1177/0049124117729703>.
- [41] B. Dahal, S.A.P. Kumar, Z. Li, Topic modeling and sentiment analysis of global climate change tweets, *Soc. Netw. Anal. Min.* 9 (1) (2019) 24, <https://doi.org/10.1007/s13278-019-0568-8>.
- [42] R. Mehrotra, S. Sanner, W. Buntine, L. Xie, Improving LDA topic models for microblogs via tweet pooling and automatic labeling, in: *Proceedings of the 36th international ACM SIGIR conference on Research and development in information retrieval*, New York, NY, USA, 2013, pp. 889–892, <https://doi.org/10.1145/2484028.2484166>.
- [43] P. DiMaggio, M. Nag, D. Blei, Exploiting affinities between topic modeling and the sociological perspective on culture: application to newspaper coverage of U.S. government arts funding, *Poetics* 41 (6) (2013) 570–606, <https://doi.org/10.1016/j.poetic.2013.08.004>.
- [44] Y. Si, J.C. Stephens, Energy justice through solar: constructing and engaging low-income households, *Front. Sustain. Cities* 3 (2021) 20, <https://doi.org/10.3389/frsc.2021.632020>.
- [45] Y. Si, Co-authorship in energy justice studies: assessing research collaboration through social network analysis and topic modeling, *Energy Strateg. Rev.* 41 (2022), 100859, <https://doi.org/10.1016/j.esr.2022.100859>.
- [46] TotalEnergies, "Our expertise in solar energy," TotalEnergies.com. <https://totalenergies.com/energy-expertise/exploration-production/renewable-energies/solar-energy>, 2022 (accessed Jun. 05, 2022).
- [47] J. Murray, How the 6 major oil companies have invested in renewable energy projects. <https://www.nsenergybusiness.com/features/oil-companies-renewable-energy/>, 2020 (accessed Jun. 05, 2022).
- [48] S. Carpenter, "After Abandoned 'Beyond Petroleum' Re-brand, BP's New Renewables Push Has Teeth," *Forbes*. <https://www.forbes.com/sites/scottcarpenter/2020/08/04/bps-new-renewables-push-redolent-of-abandoned-beyond-petroleum-rebrand/> (accessed Dec. 08, 2022).
- [49] Shell, Hydrogen, 2022 (accessed Jun. 05, 2022), <https://www.shell.com/energy-and-innovation/new-energies/hydrogen.html>.
- [50] A. Lawson, Shell consultant quits, accusing firm of 'extreme harms' to environment, *Grist*, May 30, <https://grist.org/accountability/shell-consultant-quits-accusing-firm-of-extreme-harms-to-environment/>, 2022 (accessed Jun. 03, 2022).
- [51] C. Kemfert, F. Präger, I. Braunger, F.M. Hoffart, H. Brauers, The expansion of natural gas infrastructure puts energy transitions at risk, *Nat. Energy* 7 (7) (2022) 7, <https://doi.org/10.1038/s41560-022-01060-3>.
- [52] G. Ferns, K. Amaeshi, A. Lambert, Drilling their own graves: how the European oil and gas supermajors avoid sustainability tensions through mythmaking, *J. Bus. Ethics* 158 (1) (2019) 201–231, <https://doi.org/10.1007/s10551-017-3733-x>.
- [53] E.M. Eaton, N.A. Day, Petro-pedagogy: fossil fuel interests and the obstruction of climate justice in public education, *Environ. Educ. Res.* 26 (4) (2020) 457–473, <https://doi.org/10.1080/13504622.2019.1650164>.
- [54] A. Gramsci, *Selections from the prison notebooks*, in: *Applied Theatre Reader*, 2nd ed., Routledge, 2020.
- [55] D. Nyberg, A. Spicer, C. Wright, Incorporating citizens: corporate political engagement with climate change in Australia, *Organization* 20 (3) (2013) 433–453, <https://doi.org/10.1177/1350508413478585>.
- [56] P. Newell, H. van Asselt, F. Daley, Building a fossil fuel non-proliferation treaty: key elements, *Earth Syst. Gov.* 14 (2022), 100159, <https://doi.org/10.1016/j.esg.2022.100159>.