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# Networks of climate obstruction: Discourses of denial and delay in US fossil energy, plastic, and agrichemical industries

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## Abstract

The use of fossil-derived hydrocarbons in fossil energy, plastic production, and agriculture makes these three sectors mutually reinforcing and reliant on sustained fossil fuel extraction. In this paper, we examine the ways the fossil fuel energy, plastics, and agrichemicals industries interact on social media using Twitter (renamed X as of 2023) data analysis, and we explore the implications of these interactions for policy. Content analysis of the text of tweets from the two largest US corporations and a major trade association for each sector (three discrete social media accounts for each sector) reveals coordinated messaging and identifies synergistic themes among these three sectors. Network analysis shows substantial engagement among the three sectors and identifies common external entities frequently mentioned in each sector. To understand the discursive strategies of the twitter networks of these three petrochemical derivative and fuel sectors, we propose the ***discourses of climate obstruction*** framework, adapted from and expanding on Lamb et al.'s (2020) *discourses of climate delay* framework. Our framework integrates both discourses of delay and discourses of denial because an integration of both were found in our analysis suggesting coordinated efforts to obstruct climate action. Our analysis suggests that discourses to deny and delay climate policy are aligned and coordinated across the three sectors to reinforce existing infrastructure and inhibit change. Exceptions in this alignment emerge for a few distinct sector-specific goals, including contrasting messages about biofuel. Despite some disparate views and different policy priorities among these three sectors, similar efforts to reinforce existing extractive petrochemical hegemony and undermine climate policy are clearly evident in each sector. These findings suggest that more research is needed to understand collaborative efforts among fossil energy, plastic, and agrichemical producers to influence climate and energy policy.

## 1. Introduction

Fossil fuel extraction, processing, and combustion is the primary driver of climate change and a major contributor to ecological destruction and public health risks around the world [1]. Expanding hydrocarbon processing and production, the synthesis of products derived from petroleum and fossil gas hydrocarbons, is at odds with the need to mitigate the risks of climate change and protect public health. As the climate crisis worsens and the dangers of continued fossil fuel use become more clear, political pressure to phaseout fossil fuel reliance is growing globally [2]. Around the world, hundreds of political, academic, and civil society leaders, governments at all levels, health and faith institutions, and civil society organizations have endorsed a Fossil Fuel Non-Proliferation Treaty [3], which is a global effort to foster international cooperation to accelerate fossil fuel phaseout and transition to clean energy [4]. Despite the urgent need for fossil fuel phaseout, oil and gas production has increased dramatically in the past decade, and plans for continued expansion have been approved meaning that the world is extracting more fossil fuels rather than less. Although recognition of the devastating climate impacts, human health consequences and ecological destruction associated with fossil energy has led to widespread and growing deployment of renewable energy, research on fossil fuel corporate strategies has found that fossil fuel companies have been investing in entrenching oil and gas production by expanding beyond energy and increasing non-energy end uses of petroleum products including plastics and agrichemicals [5, 6]. Advocates concerned about the proliferation of plastic pollution, and associated risks to both human and ecological health, have referred to the expanding use of plastics as the fossil fuel industry's Plan B [7].

This research acknowledges how the extraction and use of hydrocarbons in three sectors, fossil energy, plastic production, and agriculture, are interconnected (Fig 1). Despite their material resource connections, research on the extent of collaboration and coordination among these three sectors has been limited. In addition to being used for energy, the hydrocarbons processed in fossil fuels are also central to the production of both plastics and agrichemical inputs; ExxonMobil, Chevron, and Shell are some of the world's largest producers of both oil and plastic [8, 9]. Given the volatility and regulatory changes in the energy sector, plastic production has been providing more stable investment opportunities for petrochemical fuel producers [6, 10, 11] and industrial agriculture's reliance on petrochemical-derived fertilizers and pesticides is also creating steady growing demand. As of 2020 about 20% of oil is used for chemical production including plastics and 24% is used for agriculture, including transportation, marketing, and consumption in these sectors [12]. Industrial horticulture and the plastic industry are also mutually reinforcing through the heavy use of plastic throughout crop production, agricultural intensification, and crop distribution [13]. Petrochemical-derived energy, plastics and agricultural inputs are directly and inequitably damaging both human and ecological health [9, 12].

Research on bilateral connections between fossil energy and plastics [5, 9, 12] and between fossil energy and agriculture [12, 14–16] has revealed strategic coordination of lobbying efforts to resist government regulation. Although corporations in these sectors have publicly committed to climate actions such as supporting a carbon tax or funding carbon- or pollution-reducing initiatives, these organizations continue to be linked to destructive extractive activities, lobby against substantial climate policy, and fund climate disinformation [17]. Advertising companies, the public relations industry, have been connected to a decades-long strategy of extractive industries to use communications to shape public conceptions of environmental problems and acceptable responses [18]. An extensive literature on the numerous approaches to climate policy obstruction used within the fossil energy industry over time is expanding [6, 19–22] and additional research connects anti-environmental campaigns run by members of the agricultural sector to climate obstruction [23]. The objectives and roles of the plastics

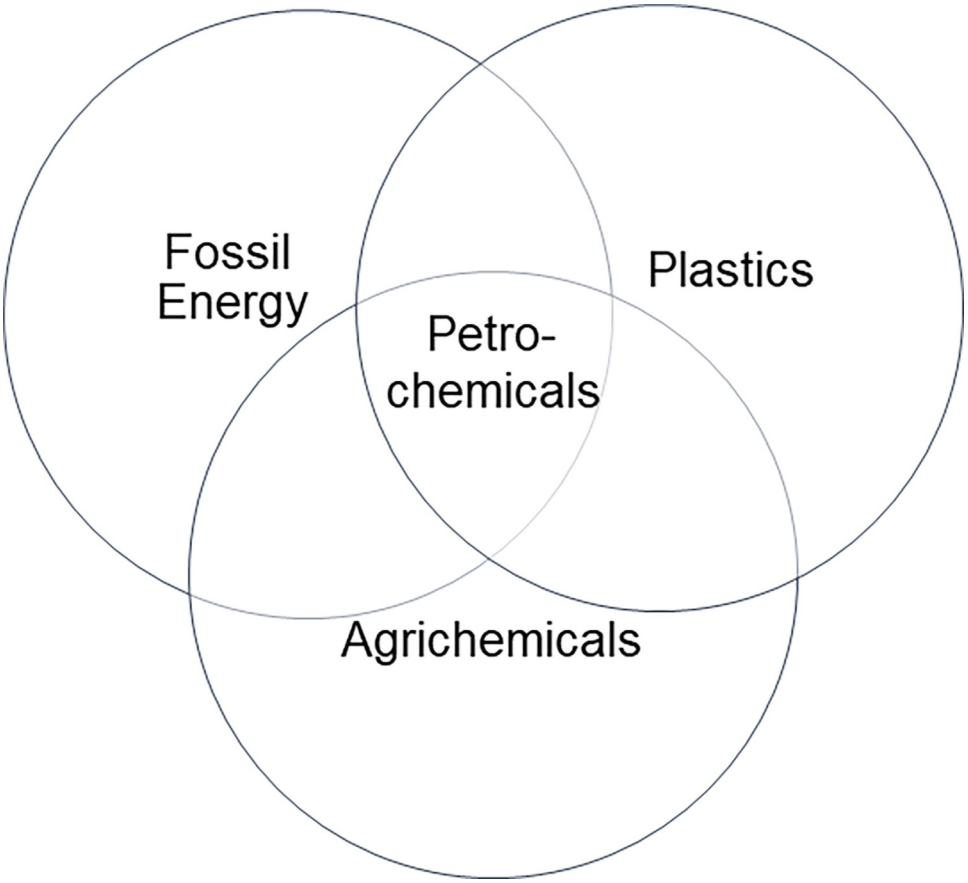


**Fig 1. Interconnections among fossil energy, plastics, and agrichemicals.** All three sectors overlap in resource inputs from petroleum and fossil gas extraction and processing. Each pair of sectors is also mutually reinforcing through production, distribution, and consumption.

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industry and agrichemicals sector in climate policy have, however, not yet been well documented, and the societal impact of these industries' strategic activities to resist climate policy remains under-analyzed.

In this paper, we report on Twitter (now called X as of mid-2023) data through analysis that explores the strategic communication of the two largest corporations and main trade association in each of the three hydrocarbon sectors in the US. We start by providing background on social media analysis and on the nine industry organizations analyzed. Next, we describe the methods we used for Twitter data extraction, network analysis, and tweet text analysis. The results section presents both the content of tweets and the networked contexts of the tweets. In the discussion, we evaluate the maps of their networks and their shared narratives to understand the nature and extent of interconnection among the three sectors and their climate policy involvement on social media. The limitations and implications of these findings are then discussed, before we conclude by placing this research in the larger context of current understanding of climate obstruction and future research directions.

## 2. Background

### 2.1 Social media analysis

Corporations use social media to engage with customers, shareholders, partner organizations, and others to influence their reputations among the public and directly communicate with

policymakers [24]. To shape public perception of their product and their corporate image, transnational and large national corporations that produce tobacco, alcohol, ultra-processed food, and fossil energy–the four major sectors that cause avoidable harms to public health [25]–appear to have deployed social media messaging as a means of resisting policy that could dampen their profits, such as petrochemical production regulations [18, 26–29]. For fossil fuels, this messaging strategy is part of efforts to maintain international political and cultural hegemony, a coordinated effort across the fossil energy industry to cooperate and consolidate power to shape public discourse and obstruct climate policy [26, 30–34]. Four types of climate policy delay narratives have been identified by Lamb et al that can describe the discourses present in fossil hydrocarbon social media: redirecting responsibility for climate change away from petrochemical derivative and fuel corporations such as to individuals, supporting non-transformative solutions to climate change such as by over-emphasizing technological innovations, emphasizing the disruptive potential of climate policy such as to development, and surrendering to climate change such as by arguing that it is already too late [35].

From 2015–2022, the social media platform Twitter gained popularity and reach, and many companies increased their communication activity on the Twitter platform, enabling discourse directly with their consumers, the public, and public figures such as policymakers. While previous research has found that industries in the fossil energy, plastic, and agrichemical sectors use social media to influence public discourse, research has not yet been conducted on the nature or extent of strategic collaboration across these sectors. Analyzing Twitter accounts of corporate entities provides time-stamped data on individual company communications and information on the extent to which companies are mentioning each other and reproducing and reinforcing each other's messaging. Analysis of Twitter content is therefore a potent tool to evaluate the ways that petrochemical derivative and fuel corporations' messaging is having the effect of publicly undermining climate action. Scholarly research has found that Twitter communications from fossil energy corporations have been targeted to global publics and policymakers to strategically delay the energy transition away from fossil fuels [26], to subtly reframe conversations and data to support positive interpretations of fossil energy corporations' activities [36], and to refocus attention away from negative environmental impacts of fossil energy such as extreme weather events [37]. These approaches exemplify transition "narrative realignment" from hydrocarbon industries that identify petrochemical-based corporations as essential to the energy transition despite a lack of transformational action [38]. We used a mixed methods framework for analyzing social media data through integrated computational and qualitative methods to select, manage and analyze a dataset of tweets from the petrochemical derivative and fuel sectors so that we could examine both the content of tweets and the social context in which they occurred [39, 40].

## 2.2 Organization selection

To assess the presence and extent of connections among the US oil and gas sector, the US plastics industry, and the US agrichemical industries, we conducted a network analysis of the tweets published by the primary corporate account of the major industry associations for each sector and the two largest companies (by production quantity) in each sector in the US (Table 1). It was challenging to select two discrete companies within each sector because oil and gas, plastics, and agrichemicals are deeply interlinked, having merged and unmerged with other companies across sectors over time. For example, some corporations, including ExxonMobil and Chevron, have highly productive arms not only in the oil and gas sector but in plastics as well. Similarly, consolidation in the chemical industry resulted in a merger in 2015 between Dow and DuPont, which split four years later back into Dow, Dupont, and Corteva, all of which are engaged in both petrochemical and agrichemical production.

**Table 1. Twitter accounts of major oil and gas, plastics, and agrichemical organizations.**

| Sector | Industry Associations | Corporations | Twitter Handles |
|---|---|---|---|
| Oil and Gas | American Petroleum Institute | ExxonMobil<br>Chevron | @APIenergy<br>@exxonmobil<br>@Chevron |
| Plastics | American Chemistry Council | Dow Chemical<br>DuPont | @AmChemistry<br>@DowNewsroom<br>@DuPont_News |
| Agrichemicals | American Farm Bureau | Corteva<br>FMC Corporation | @FarmBureau<br>@corteva<br>@FMCCorp |

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ExxonMobil, the third largest company and largest oil and gas company in the US in 2022 by revenue at $413.7bn, of which $56bn was profit (45% higher than the previous year) [41], is the most recent agglomeration of several longstanding oil and gas corporations that resulted from the merger of Exxon, which combined Jersey Standard, Enco, Esso, and Humble in 1972, and Mobil, formerly Standard Oil of New York, in 1999 [42]. Although the corporation has studied and understood the anthropogenic basis of climate change and the danger it poses to global public health since the early 1970s, ExxonMobil has continued to use messaging that has encouraged climate denial, delay, and counter-lobbying up to and in the present day, including through what might be construed as the greenwashing of its own products [43–45]. Beyond oil and gas, ExxonMobil also advertises its production of plastic materials including polyethylene and polypropylene [46] and "hydrocarbon fluids for agrochemicals" or agrichemicals [47]. In addition to the primary @exxonmobil handle that we analyzed, there were several regional Twitter handles such as for ExxonMobil EU that we did not analyze (as was the case with all other analyzed entities). ExxonMobil also has two distinct Twitter handles particular to plastics, ExxonMobil Chemical @XOM_Chemical, and philanthropy, ExxonMobil Foundation @XOMFoundation.

Chevron is the second-largest oil and gas company and tenth largest company in the US in 2023 by revenue with $246.3bn, of which it made over $35.5bn profit in 2022 (52% higher than the previous year) [41]. Like ExxonMobil, Chevron's roots are in a Standard Oil (of California) merger, in this case with Gulf Oil and Texaco [48]. While Chevron has substantially contributed to climate obstruction similar to ExxonMobil [19, 49], Chevron has also been implicated in obstruction of environmental justice in Ecuador in international courts through the series of court cases that resulted in the "Chevron Doctrine" [50]. Similar to ExxonMobil, Chevron has several Twitter handles specific to geographic areas as well as handles for particular parts of the corporation: @chevronphillips for Chevron Phillips Chemical, which is the company's joint venture with Phillips 66 (the 17$^{th}$ largest company in the US in 2023, formerly a part of ConocoPhillips, which is separately the 49$^{th}$ largest company in the US [41]) that produces plastics and agrochemicals, @ChevronDelo for Chevron's synthetic lubricants, @REGbiofuels for Chevron Renewable Energy Group, @ChevronFCU for the Chevron credit union, and @chevron_careers and @ChevronStemZone for Chevron's recruiting. @AmazonPost, is the handle Chevron uses to tweet about the Ecuadorian court case [51]. There is even @ZooSchoolyyc for the Chevron Open Minds Zoo School, a conservation education center started and funded by Chevron in Calgary, Canada, the website of which features prominent Chevron branding [52].

Dow Inc. is the 75$^{th}$ largest company in the US by revenue with $56.9bn in 2022, of which $4.6bn was profit, and the largest American chemical company [41]. Dow has merged or combined ventures with a number of chemical companies including Union Carbide and DuPont,

although DowDupont re-separated a few years after their merger to become Dow, DuPont, and Corteva, which combined the other companies' agricultural units. Dow is now a material science corporation that produces chemicals for a wide range of end uses, more than half of which are categorized as "packaging and specialty plastics" [53]. The ultimate effect of these mergers has been the diffusion of responsibility for environmental harm, as in "the world's worst environmental disaster in Bhopal India," a Union Carbide pesticide gas leak that officially killed 2,259 people in 1984 and injured hundreds of thousands more in an ongoing public health crisis [54]. Dow has been seen to support discourses of climate denial, e.g., by funding the climate denial organization the Competitive Enterprise Institute [17, 55]. As with Chevron and ExxonMobil, Dow has multiple location-specific Twitter handles, as well as handles for the company's public policy branch, @DowPolicy, silicone-specific branch, @dowsilicones, packaging materials, @DowPackaging, employees' credit union, @DCECU, and various funded sports including racing and tennis.

The second-largest plastics producer is Dupont de Nemours, Inc. (DuPont), which is the sixth largest American chemical company by revenue with $16.5 billion in 2022, of which $5.9bn was profit, and the second largest focused on plastics, polymers, and resins [41]. Upon separation from DowDuPont, DuPont became a "specialty products" company, including electronics, nutrition and health, building, and other materials with familiar brand names including Styrofoam, Teflon, Tyvek, and Kevlar [56]. DuPont also came to an agreement with FMC Corporation to exchange some of DuPont's agrichemical portfolios, including herbicides and insecticides, for FMC's Health and Nutrition portfolio, including food texturants and pharmaceutical excipients [57]. DuPont appears to have been aware that its plastic and resin products are toxic and hazardous to humans since as early as the 1950s, in part due to the impacts of per-and poly-fluorinated substances (PFAS), but has publicly downplayed and refuted this research [58–60]. DuPont has also effectively supported climate obstruction, including by downplaying climate science as a member of the Global Climate Coalition in the 1990s [21, 61]. On Twitter, Dupont does not have location-specific accounts but instead has a primary account, @DuPont_News, accompanied by sector-specific accounts including Performance Building Solutions, @dupontpbs, Water Solutions, @DuPontWater, and Personal Protection, @DuPontPPE, brand-specific accounts such as @TeflonBrand, and a conference-specific account, @DuPontSpotlight.

Corteva Agriscience was spun off during the dissolution of DuPont and Dow Inc in 2019 with the agrichemical portfolios of both corporations, including fungicides, herbicides, insecticides, seeds, and fertilizers [62]. It is the fourth largest pesticide producer in the world by revenue after Syngenta, Bayer, and BASF, and the largest US-based pesticide producer with $17.5bn revenue and $1.1bn profit in 2022 [41, 63]. Corteva (formerly DowDuPont) has shared messaging that has effectively undermined public health research that highlighted concerns regarding potential impacts of GMOs and agrichemicals including pesticides and glyphosphate, for instance by funding marketing campaigns and academics with industry ties [64]. Corteva has a primary Twitter account, Corteva Agriscience @corteva, and several accounts specific to locations, e.g., Corteva Japan @CortevaJP and Corteva Uruguay @CortevaUY, or specific to (seemingly US) products, e.g., Turf and Ornamental @CortevaUSTurf, Range and Pasture @CortevaPastures, and Vegetation Management @CortevaVegMgmt. Corteva also runs two educational accounts, Boas Praticas Agricolas @corteva_bpa for Brazil and Catedra Corteva @catedracorteva in collaboration with the University of Seville, and has one small event-specific account, from the Makerere University Corteva Plant Science Symposium 2019 @Marcci2019, sponsored by and named for Corteva.

FMC Corp was founded as the Bean Spray Pump Company, an insecticide technology company, in 1883, was renamed Food Machinery Corporation in 1928, and was renamed the Food

Machinery and Chemical Corporation in 1948 [65]. FMC is the 6th largest agrochemical firm globally by revenue, and is the 2nd largest based in the US after Corteva with over $6bn revenue in 2022 of which $1.4bn is profit [63]. Over time the corporation has acquired and divested various portfolios including lithium and phosphorus ventures and as of 2023 produces fungicides, herbicides, insecticides, and applicators [66]. While FMC has released a statement regarding its concern for climate change and biodiversity loss that includes a commitment to net-zero GHG emissions by 2035, the same statement highlights that GHG regulation "may result in increased costs of energy, additional capital costs for emissions control or new equipment, and/or costs associated with cap and trade or carbon taxes" [67]. The company has been described as publicly misrepresenting and denying climate science and opposed climate policy efforts in written testimony to the EPA in 2009, has donated to the libertarian think tank the Competitive Enterprise Institute, is a member of CropLife International and the American Chemistry Council, and has spent nearly $32mil on lobbying agencies and officials of the US government since 1998 [68–71]. On Twitter FMC has a primary account, @FMCCorp, regionally specific accounts such as @FMCAgUS, @FMCAgCanada, @FMCAgroUK, @FMCANZ for Australia and New Zealand, and @fmcapac in the Asia Pacific region, and sector specific accounts such as @FMCpest for pesticides and @FMCturf for lawn and golf course maintenance.

For industry associations, we selected the American Petroleum Institute, which represents the oil and gas industry, the American Chemistry Council, which represents plastics, and the American Farm Bureau, which represents agrichemical producers.

The American Petroleum Institute (API) is the primary trade association for US oil and gas. API culturally supports the endurance of the fossil energy sector with messaging that has the effect of reframing energy industries in terms of the (negative) impacts of environmental policy [49, 72, 73]. The group represents 600 members in five segments: production (upstream), processing, storing, and transporting (midstream), refining and marketing (downstream), fracked gas including pipelines, and marine exploration [74]. Both ExxonMobil and Chevron are members. API has a long history of activities that could be characterised as supporting climate denial, delay, and obstruction, including spending $120mil on lobbying since 2000 and funding various organizations with tens of millions of dollars including research institutions and climate denial think tanks [17, 75, 76]. API's main Twitter account is @APIenergy, although the association also has smaller general accounts, @APIenergies and @API_News, region-specific accounts including for Pennsylvania @API_Penna, Ohio @APIOhio, and Houston @API__Houston, and an account no longer in use that was seemingly geared toward opposing economic regulations on petrochemicals, @API_Tax.

The American Chemistry Council (ACC) is the primary trade association for the US chemicals industry. Members include not only chemical manufacturers including all six of the petrochemical corporations in this study and international petrochemical producers, but associate member consulting groups including Deloitte, McKinsey & Co, and PWC [77]. ACC has notably been characterised as opposing environmental regulation intended to protect public health in the US [78, 79] and has been implicated in efforts to reverse plastic waste reducing regulations including specifically in Africa [80]. ACC spends enormous amounts of money on US lobbying and campaign contributions; in the 2022 cycle alone the organization spent nearly $700,000 on campaign contributions and nearly $20mil on lobbying to reduce business costs including tax and regulatory burdens of their member organizations [81]. ACC has several Twitter accounts including a primary account, @AmChemistry, a sector-specific account for Circular Packaging @AdvancePackaging that has not been used since 2021, low-activity accounts for events and safety information @AmChemEvents, @ChemSecurity, and @CFATS,

an active promotional account that claims to share safety information, @ChemSafetyFacts, and a Delaware-specific account @DEChemCouncil that is very active.

Finally, the American Farm Bureau Federation (AFB) is an industry organization for US farmers at the state and county level that conducts advocacy, engages in policy, and supports member and community development and activism. AFB is openly opposed to a "near term" end of fossil energy use [82, 83] and its state groups have used their resources in such a way as to effectively undermine climate science and regulation including as part of the Global Climate Coalition and through lobbying on issues like carbon cap and trade, the Clean Air Act, GHG regulations and reporting, the Infrastructure Investment and Jobs Act, and the Inflation Reduction Act [84–86]. Since 2012 AFB has spent more than $2mil per year on lobbying, and over $4mil in 2017 alone [86]. On Twitter, AFB's primary account is @FarmBureau and there are a number of state and county-specific accounts. There are also accounts for AFB's special projects focused on education, @AgFoundation, advocacy, @FBAdvocacy, and market information @FBMarketIntel.

## 3. Methods

### 3.1 Twitter data extraction

As a first step, the data were extracted using Twitter Application Programming Interfaces (APIs) V2 for academic research, a platform that allowed users to download tweets including tags and comments by users and through keywords. Tweets were downloaded during January and February 2023 including all tweets starting from the first tweet each user handle posted as early as 2008 through January 2023. This yielded a dataset of 125,340 tweets (excluding duplicate tweets from the same handle) from 2008 to 2023 (Fig 2). Only English language tweets were extracted, and we did not include tweets that were replies to another tweet. Twitter user handles (which could be a retweet or an original tweet) were analyzed using social network analysis based on the relationships embedded in the tweets. The content of the tweets was analyzed using thematic text analysis.

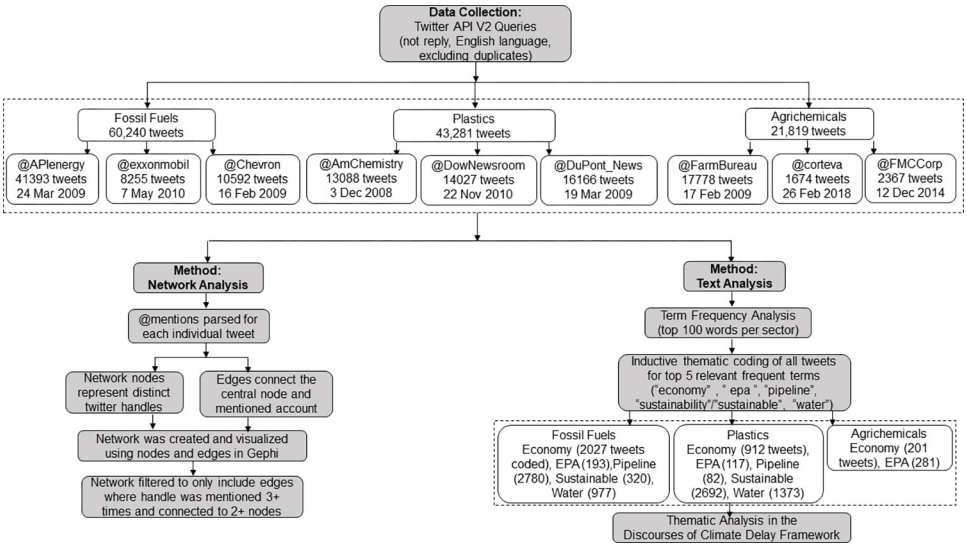


**Fig 2. Procedural approach.** Our mixed methods approach and key terms for each type of analysis are detailed in the two branches of network analysis and text analysis.

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The most informative descriptive network metric we calculated is degree centrality. Degree centrality reflects the connectedness of a node by counting the number of edges that connect to each node [87]. Because we are exclusively examining mentions by the nine central nodes, the average degree centrality will reflect the extent to which nodes tend to be mentioned by multiple of the central nodes or just one. We also used other metrics to present a descriptive summary of the network. The *modularity* score shows how densely connected subgroups are within the broader network [88]. A modularity score that is closer to 1 means that the detected groups are strongly connected. The *clustering coefficient* of a given node is the ratio of the actual number of edges between a node's neighbor nodes to the total number of possible edges, which measures the degree to which nodes cluster together. It measures the average probability of interconnection between two nodes connected to the same node in the network and reflects the degree of network aggregation. Again, because we are looking only at the mentions by nine central nodes and not connections between the mentioned nodes, the average clustering coefficient will be a low number that reflects the extent of shared connections between only the 9 central nodes. Finally, *average path length* shows the efficiency of the network's information-sharing by measuring the distance between pairs of nodes in the average number of steps along the shortest paths for all possible pairs of network nodes. The path lengths will be between 1 and 3 as each path will go through one or two of the central nodes. A shorter average path length will show higher interconnection among the mentions of the central nodes.

## 3.2 Network analysis

We constructed a network to examine the relationships among the nine central accounts and the handles they mention. Analysis of this network shows the connections among the Twitter handles across sectors and explores the strength of ties within sectors. To conduct this analysis, we first extracted the user handles mentioned in each published tweet by the central nodes using Python 3.11.2. The nine central accounts and each user handle they mentioned are the nodes in the network. Edges identify the relationships between nodes; they are the connections from the central node to each account mentioned in each tweet. We built the edge list in Python that tabulated the number of mentions, or edge weight, of each node by the central accounts. This identifies the most frequently mentioned organizations and the strength of those individual relationships from the central nodes outward. Then we imported the weighted edge list to Gephi, the leading visualization and open-source software for graphs and networks [89]. We imported the data to the Gephi 0.10.1 software via the default import module to calculate network statistics and visualize the network. Because we did not examine any response tweets or the retweets by actors other than our nine organizations of interest, the dataset is exclusively outgoing communication from the nine organizations. Still, by examining the mentions in each tweet, we studied the social media community of each network as well as the extent of shared external relationships that connect the organizations outside the petrochemical derivative and fuel sectors.

## 3.3 Text analysis

After extracting tweets from the nine twitter accounts and removing duplicates, we identified the major topical areas across the dataset of tweets by calculating the most frequent terms used in the dataset in Python 3.11.2 [39]. Of the most frequent terms, terms in the top 100 most frequent words in at least one sector, we manually selected 5 terms of highest relevance to climate policy obstruction to compare the narratives in tweets within these topics: economy, EPA, pipeline, sustainability, and water. These 5 terms appeared either in the tweets of all three

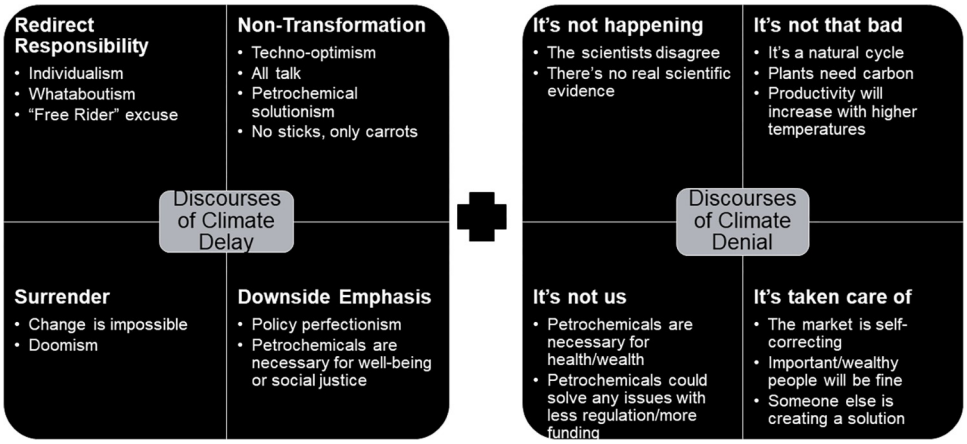


**Fig 3. Discourses of climate obstruction.** This framework integrates two frameworks to characterize discourses of climate obstruction (adapted from Lamb et al., 2020 and Cook, 2020). Each quadrant shows examples of the four categories of discourses in each framework.

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sectors (economy and EPA) or two of the three sectors (pipeline, sustainability/sustainable, water). We searched the tweets for each of these keywords, and for EPA searched with dashes before and after the acronym to exclude irrelevant words that include the letters epa. We then inductively created a codebook of the narrative themes under each of the five topics and imported the data into NVivo to thematically code each tweet that included one of these five terms from our dataset.

We then analyzed these codes in a new hybrid framework of discourses of climate obstruction that combines the discourses of climate delay [35] and climate myths [90] framework to assess the relevance of the types of discussions of each tweet topic to policy obstruction (Fig 3). As we were conducting analysis using the Lamb et al Discourses of Climate Delay framework outlined in section 2.1, we also identified a need to similarly describe different types of outright climate denial found in these tweets [91]. Therefore, we synthesized four discourses of climate denial based on existing research and adapted from Cook's taxonomy of climate myths [90]. These are, first, "It's not real", outright denial of climate science consensus, next, "It's not bad", denial of the severity of climate change, then "It's not us", denial of the role of fossil-derived hydrocarbons in climate change, and finally "It's taken care of", denial of the need to change behavior [90, 92, 93].

The discourses of climate obstruction framework addresses similar social phenomena to discursive carbon lock-in, in that both discourses of delay and denial ultimately contribute to carbon lock-in and sustained fossil fuel dependence, such as through the promotion of bridge fuels [94]. However, this framework is distinct in that it allows for interrogation of the narrative approaches of these discourses, rather than examining their interactions with other factors of carbon lock-in.

## 4. Results

### 4.1 Twitter data descriptive summary

The dataset of 122,710 tweets, included 58,100 tweets from the fossil energy industry, 42,931 tweets from the plastics industry, and 21,679 tweets from the agrichemical industry (Table 2). Within this, 13,214 tweets contained the keywords of interest (sustainable/ sustainability, EPA, pipeline, economy, water), including 6,297 tweets from the oil and gas sector, 5,176 tweets

**Table 2. Tweet references by sector.**

| Sector | Total tweets (excluding duplicates within handles) | Total tweets (excluding duplicates between handles) | Total containing words of interest | Mentioning sustainable/ sustainability | Mention EPA | Mention pipeline | Mention economy | Mention water |
|---|---|---|---|---|---|---|---|---|
| Oil and Gas | 60,240 | 58,100 | 6,297 (10.8% of non-duplicate tweets) | 320 (5.1% of tweets with words of interest) | 193 (3.1%) | 2,780 (44.1%) | 2,027 (32.2%) | 977 (15.5%) |
| Plastics | 43,281 | 42,931 | 5,176 (12.1%) | 2,692 (52.0%) | 117 (2.3%) | 82 (1.6%) | 912 (17.6%) | 1,373 (26.5%) |
| Agrichemicals | 21,819 | 21,679 | 1,741 (8.0%) | 525 (30.2%) | 281 (16.1%) | 28 (1.6%) | 201 (11.5%) | 706 (40.6%) |

https://doi.org/10.1371/journal.pclm.0000370.t002

from plastics industry, and 1,741 tweets from the agrichemical industry. The percent of tweets containing keywords per sector is reflective of the overall percent of tweets among sectors. Fossil fuel organizations made up 47% of tweets and 47% of keywords, plastics composed 35% of tweets and 39% of keywords, and agrichemicals made up 18% of tweets and 13% of keywords.

Our descriptive data show that there are 3407 nodes and 3762 edges in the network (Table 3). There is only one connected component in the network, meaning that all nodes are connected and there are no isolates. This is due to our definition of the network as containing solely mentioned nodes, and because every central node mentioned at least one handle. The average degree centrality is 1.104, which reflects that most of the mentions are mentioned only by one central node. The modularity score is 0.677, indicating a relatively strong ($> 0.5$) community structure. In addition, the average clustering coefficient is 0.036, showing that there is a small amount of clustering by the central nodes that is counterbalanced by the larger number of handles mentioned by one node. Finally, the average path length is 2.271, which shows that the mentioned handles on average are mentioned by the same central node.

All nine of the organizations of interest were mentioned by multiple of the other organizations of interest, which shows relationships of varying degrees among all of the hydrocarbon-based entities. This reflects a substantial connection among the organizations in the three sectors, particularly between fossil energy and plastic corporations. The most central Twitter account, which is connected to the most handles in the network, is API, then Dow, then ACC (Fig 4, Table 4).

## 4.2 Network analysis results

To some extent, the nodes' centrality is a result of the duration of the account and the rate at which the account tweets (Table 4). ExxonMobil was the most frequently mentioned handle due to a large number of mentions by API. ACC and Dow were each mentioned by seven of the eight other accounts, whereas FMC was the least mentioned (only by ACC). ACC was the only account that mentioned all 8 other entities, despite only having made the 5$^{th}$ most mentions, and Corteva mentioned the fewest other handles, only Dow and AFB. For some of the nodes in Table 4 (marked by asterisks), the primary account was not tagged, but another variation was; we include these subaccounts in the analysis only for this table to show the presence of interaction among the entities even if not using the current official handle and not for the network analysis. For example, Dow's primary account is DowNewsroom, but API and

**Table 3. Total Twitter network statistics.**

| Nodes | Edges | Average Degree Centrality | Modularity | Avg. Clustering Coefficient | Avg. Path Length |
|---|---|---|---|---|---|
| 3407 | 3762 | 1.104 | 0.677 | 0.036 | 2.271 |

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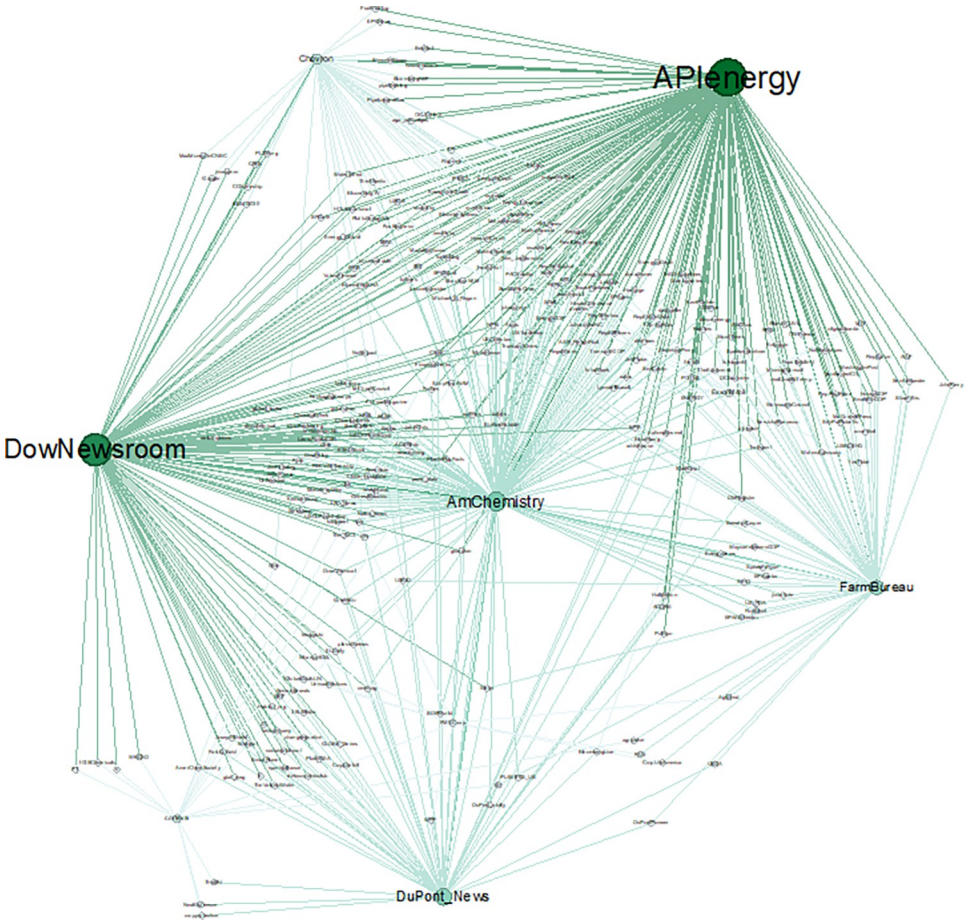


**Fig 4. Twitter mention networks among fossil energy, plastic, and agrichemical organizations.** This figure presents an overall view of the network not grouped by sector. All nodes have a degree centrality equal to or larger than 2. There are 284 nodes (8.34%) and 639 edges (16.99%) visible in this visualization. Nodes are sized by degree centrality such that a larger node indicates a bigger value of degree centrality.

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ExxonMobil tagged "Dow", while AFB tagged "DowPackaging", and Corteva tagged "DowAgroUK". Still, all nine of the accounts have mentioned or been mentioned by at least four other accounts in the group of researched organizations, reflecting the extent of inter-relationships between the petrochemical derivative and fuel organizations.

Many of these accounts have also mentioned the same common handles, indicated in Fig 4 by nodes attached to multiple lines. This suggests their participation in a shared community of relevant actors, rather than merely in sector-specific isolation or exclusively with members of the same industry, such as fossil energy production. To assess the extent of interconnection across sectors (i.e., between plastic and agrichemical handles), we also analyzed connectivity at the sector, rather than individual handle, level (Fig 5). We filtered for nodes that are connected to at least two of the nine organizations and have been mentioned at least 3 times in tweets or retweets to limit the set only to Twitter handles that are relevant to multiple organizations. We then manually sorted the nodes in the graphic to group them by the sector of the mentioning organization. We found that each pair of sectors shares at least fourteen mentioned Twitter handles (agrichemicals and fossil energy), and up to 152 shared mentions (fossil energy and plastics). The fossil energy and plastics sectors have the most overlap in mentioned handles, and the fossil energy and agrichemical sectors have the least overlap. There are also 43 handles

**Table 4. Mentions and rank among organizations of interest.**

| | API | EM | CH | ACC | DOW | DUP | AFB | COR | FMC | Total Tags |
|---|---|---|---|---|---|---|---|---|---|---|
| **API** | | 255 tags (15th most tagged) | 154 (28th t) | 47 (105th t) | 1 (1662nd t) | 0 | 4 (707th t) | 0 | 0 | 48908 (3534 entities) |
| **EM** | 63 (5th) | | 1 (412th t) | 12 (41st t) | 2 (229th t) *"Dow Chemical" | 1 (412th t) | 0 | 0 | 0 | 9125 (1055) |
| **CH** | 74 (13th t) | 1 (1056th t) | | 1 (1056th t) | 3 397th t) *"Dow Chemical" | 0 | 0 | 0 | 0 | 15903 (3494) |
| **ACC** | 21 (70th t) | 106 (10th t) | 3 (511th t) | | 45 (33rd t) | 83 (18th t) | 2 (673rd t) | 1 (1036th t) *CortevaUS | 19 (79th t) | 17576 (2490) |
| **DOW** | 0 | 3 (561st t) | 8 (232nd t) | 73 (17) | | 10 (192nd t) | 0 | 1 (1164th t) | 0 | 20417 (2707) |
| **DUP** | 0 | 5 (571st t) | 1 (2049 t) | 44 (59th t) | 21 (121st t) *"Dow Chemical" | | 2 (1290th t) | 3 (833rd t) | 0 | 29968 (6343) |
| **AFB** | 0 | 0 | 0 | 7 (219th t) | 1 (912th t) *"Dow Packaging" | 9 (179th t) *"dupontpioneer" | | 3 (435th t) *CortevaUS | 0 | 22733 (6343) |
| **COR** | 0 | 0 | 0 | 0 | 1 (155th t) *"Dow AgroUK" | 0 | 1 (155th t) | | 0 | 2086 (451) |
| **FMC** | 0 | 0 | 0 | 15 (8th) | 0 | 1 (112th t) | 1 (112th t) | 3 (48th t) | | 2590 (353) |

*—different corporate handle than selected above, t—tied for tag rank

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that were mentioned by at least one organization in all three sectors, which are shown in the center of the figure. The most frequently referenced twitter handle across all nine organizations that is not one of the studied organizations or their employee was the EIA (@EIAgov) with 813 mentions, followed by the U.S. EPA (@EPA) with 795 mentions, then the Wall Street Journal (@WSJ) with 517 mentions. This shows a high level of policy or regulatory

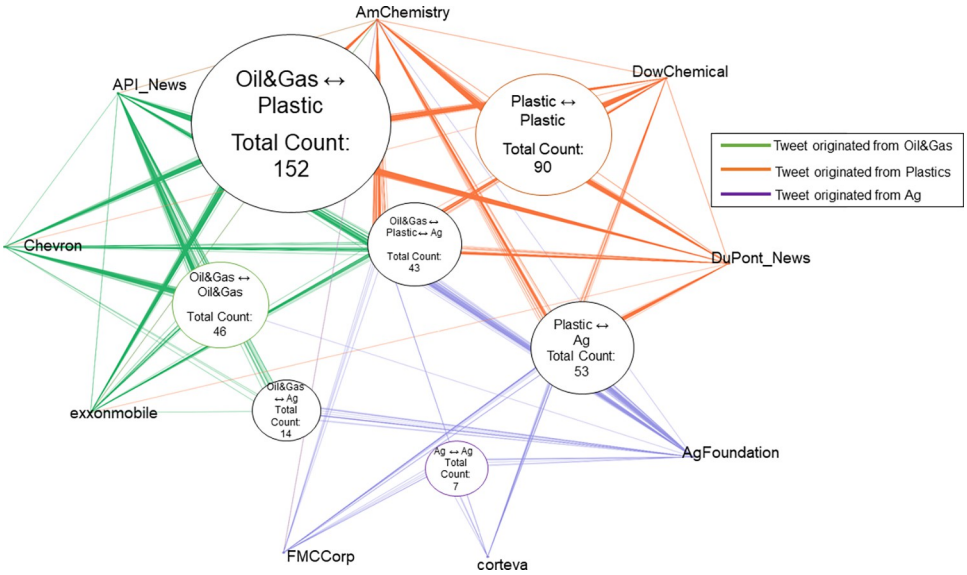


**Fig 5. Network groupings by sector.** This figure shows how many Twitter handles are mentioned by actors in multiple hydrocarbon-based sectors to highlight the extent of shared connections not only within but across sectors. The 407 nodes in this graphic were mentioned at least three times and are connected to at least two nodes. Green edges show connections to fossil energy, red edges show connections to plastics, and blue edges show connections to agrichemicals.

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**Table 5. Industries of Twitter handles mentioned 3+ times by 2 or more hydrocarbon organizations.**

| *rank* | *industry code* | *number of handles* | *rank* | *industry code* | *number of handles* |
|---|---|---|---|---|---|
| *1* | *News* | *113* | *12* | *education (academia)* | *8* |
| *2* | *Hydrocarbon* | *63* | *13* | *political issue ("grassroots")* | *8* |
| *3* | *Politician* | *43* | *14* | *civilian* | *5* |
| *4* | *Corporation* | *32* | *15* | *education (general)* | *4* |
| *5* | *Labor* | *24* | *16* | *finance* | *3* |
| *6* | *Government* | *23* | *17* | *charity/non-profit (sustainability)* | *2* |
| *7* | *political group* | *23* | *18* | *think tank* | *3* |
| *8* | *charity/nonprofit* | *15* | *19* | *social media* | *2* |
| *9* | *education (k-12)* | *13* | *20* | *lobbying* | *1* |
| *10* | *employee of central node* | *11* | *21* | *healthcare* | *1* |
| *11* | *event (education)* | *10* | ***total*** | | ***407*** |

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engagement, particularly with energy and environmental issues, across the U.S. petrochemical derivative and fuel industries.

Table 5 shows the industry codes for the nodes grouped in Fig 5. The most frequently mentioned type of account is news media accounts, of which 112 handles were mentioned, followed by organizations that produce or process hydrocarbons, 63, and politicians, 43. While the news organization and hydrocarbon organization mentions reflect Twitter's common use by businesses as a site for sharing or broadcasting news information and updates, the mentions of politicians, government organizations, political entities, political issue groups, think tanks, and lobbyists suggests the further use of Twitter as a site of political and regulatory engagement.

Notably, the petrochemical derivative and fuel organizations frequently mentioned k-12, general, and higher education organizations, which also indicates a focused effort to shape or at least interact with teaching and learning at all levels. Connections to educational organizations may indicate efforts on the part of the organizations to improve their image by providing charitable donations or to shape education such as by funding research on the benefits of their industries. The latter case is exemplified in the tweet where API energy cited a Drexel study funded by PennEast [95] as evidence of the potential benefits of the PennEast pipeline construction: *"Drexel University study*: *PennEast Pipeline will lead to more #jobs and lower prices"* (APIenergy, 11 February 2015) (Links removed—all full tweets listed in Appendix A). In an example of the former approach, Chevron tweeted about its $1.6 million donation to the Thurgood Marshall College Fund,

> *As part of our racial equity plan, we support the Thurgood Marshall College Fund (TMCF). Our sponsorship contributes $1.6 million to support college educations. Read more in our Corporate Sustainability Report.* (Chevron, 21 June 2022).

Connections to charities, medicine, and educational events similarly evince efforts to improve the public image of the hydrocarbon organizations. However, many of these efforts do not seem to acknowledge or counteract the public health and ecological damages caused by petrochemical processing. For example, API touted the sustainability efforts of oil and gas companies working in partnership with conservation organizations, but did not mention that the conservation organizations are both focused on preserving game for hunters rather than the health of ecologies jeopardized by pipeline projects:

*API Blog: API's recent partnership with Pheasants Forever and Quail Forever to enhance habitat in pipeline rights-of-way and other facilities is a new example of ways oil and natural gas companies are supporting conservation* (APIenergy, 12 July 2022).

### 4.3 Priorities revealed in text analysis

Within the five selected topics: Economy (3,140 tweets), EPA (591), Pipeline (2,862), Sustainable/Sustainability (3,012), and Water (2,350), we inductively and iteratively coded several major recurring themes (Fig 6). The full texts of every tweet referenced in this section are available in S1 Data. One theme that recurred across all of the topics was that of the benefits that the organizations contribute to society in the relevant subject area. For example, the ACC tweeted that *"Federal approval of Keystone XL pipeline is good news for revitalized #MFG [manufacturing] & new jobs"* (AmChemistry, 24 March 2017). Similarly, the AFB twice shared the same tweet that simultaneously presses the importance of agriculture to the US economy and advocates for a particular policy, the Trans-Pacific Partnership (TPP) trade agreement: *"If #TPP is Passed:U.S. farmers and ranchers will add more than 40,100 jobs to the economy"* (FarmBureau, 10 May 2016).

In all of the topics there is also a clear emphasis on sharing news about the topic. This use of social media to disseminate company-related news is anticipated and prevalent. The AFB, for example, shared regulatory journalism accompanied by perspective when they tweeted *"NY Times Ombudswoman dismisses EPA complaints about coverage of water rulemaking overreach #DitchTheRule"* (FarmBureau, 27 May 2015). Less obvious but still clear is the recurring theme of educational resources shared by the organizations relative to each topic area for the general public, such as in the API's tweet broadcasting a report, *"Report: #Pipelines Are One of the Safest Ways to Transport Energy"* (APIenergy, 19 August 2016). Petrochemical derivative and fuel organizations have also long interacted directly with educational institutions both online and

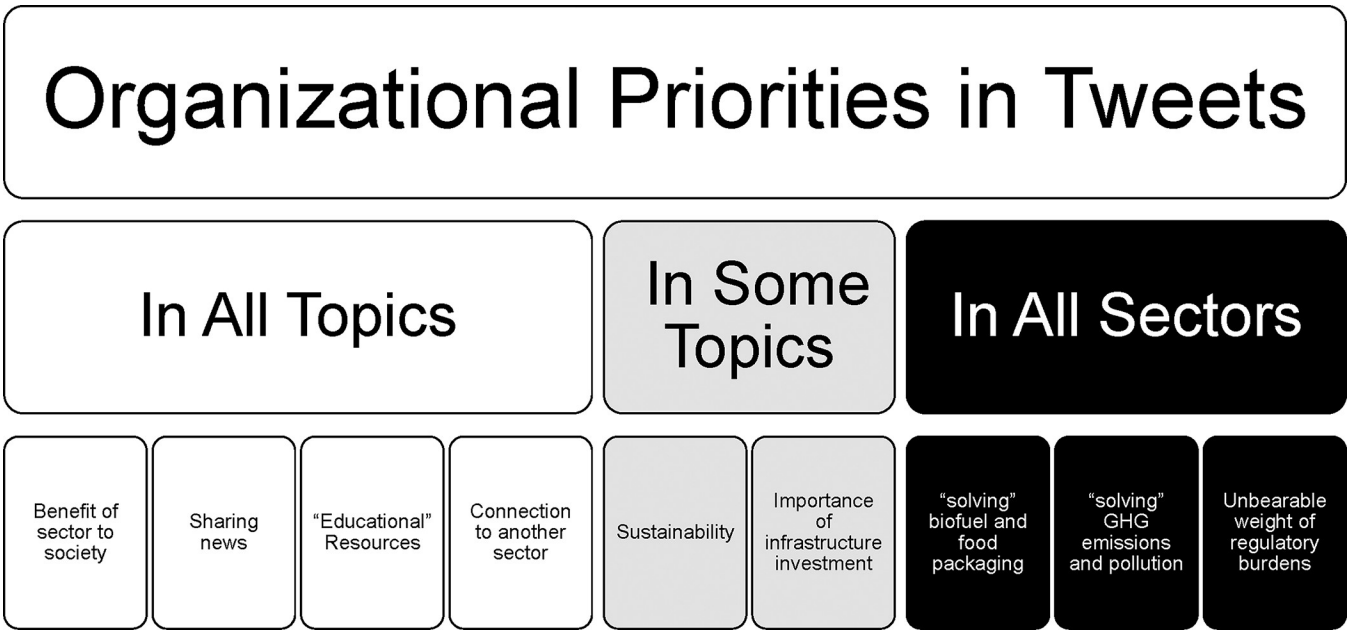


**Fig 6. Organizational priorities in tweets.** This figure conceptually maps the themes discussed in section 4.3 broken down by whether they appear in all topics, in some topics, or across all sectors.

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in person, as shown in this tweet from Chevron: *"Emphatic support 4 @PLTWorg @Chevron preparing students for the global economy"* (Chevron, 14 July 2014).

In all five of the topic areas, the hydrocarbon organizations' tweets draw connections on the topic to another of the three sectors. For example, the plastics organizations tweets included 15 tweets explicitly connecting petrochemicals with improved agricultural production, as in this tweet from Dow: *"[Dow's] innovative pipeline are driving performance in ag,"* (DowNewsroom, 26 February 2015). Similarly, all three accounts connected energy issues to economic productivity, such as in the tweet from the ACC about fracked gas: "*Natural gas has an important role in a strong #Economy, a lower emissions future, and a reliable, resilient energy & electricity system.*" (AmChemistry, 13 January 2023).

Two themes appeared frequently but not in every topic for every sector. First is the concept of sustainability. Beyond the Sustainability/Sustainable topic area, sustainability also arose in the topics of economy in tweets from fossil energy and agrichemicals, and on the topic of pipelines from fossil energy and petrochemicals. The AFB tweeted, for example,

> *A robust agriculture industry is essential to our economy, national security and environmental sustainability. We must work together to ensure U.S. agriculture has the resources it needs to continue to provide and fill these essential farm jobs. (FarmBureau, 8 February 2021).*

The API similarly promoted the "high environmental standards" of the gas and oil industry, for this particular tweet in PA:

> *Pennsylvania plays a critical role in addressing the soaring global demand for energy. The Keystone State's natural gas and oil industry helps power our economy safely and with high environmental standards. Learn more from @API_Penna in the @PittsburghPG* (APIenergy, 22 August 2022).

And DuPont touted its own sustainability efforts: *"In Dordrecht, DuPont worked w/ HVC to build a steam pipeline that helps reduce CO2 emissions by 30%! #sustainability"* (DuPont_News, 11 March 2014).

Second are tweets with themes relevant to the importance of infrastructure, particularly connected to security, water, and railroads. Generally these advocate for the importance of infrastructure that is either needed by or supported by the organizations in an effort to advocate for funding the existence of petrochemical infrastructure, such as API's argument that *". @SecretaryPerry: #Natural gas & #oil #pipelines are integral to national #security"* (APIenergy, 15 May 2018).

As opposed to the above cross-topic themes, some themes more notably connect the three sectors. For example, emphases on biofuels and food packaging explicitly concern all three sectors. Enthusiasm for the potential environmental benefits of replacing oil with biofuels can distract from the ways that biofuels require embedded petrochemical supply chains for their production in agrichemical inputs, prolong single-user gas car infrastructure, reduce the agricultural industry's capacity to produce food sustainably, and contribute directly to greenhouse gas emissions [15]. Similarly, plastic food packaging, especially single use plastic packaging, requires petrochemical inputs for production and even when recycled, can only be recycled a few times before it lingers (or is illegally dumped [96]) permanently in the environment, shedding microplastics that can have toxic effects on humans and our environments [12]. The nine organizations' tweets appear to indicate a promotion of these two issues despite understanding of their role in the dynamics underlying them. For example, ExxonMobil explicitly recognizes the burden of biofuels (it continues to promote) on the food system, *"Algae biofuels could pose*

*less of a challenge to food and freshwater supplies."* (ExxonMobil, 9 October 2017). Similarly, clearly recognizant of current limitations in food packaging, Dow tweeted that *"Dow expands offering of food packaging solutions w/ HYPOD [Trademark] water-based polyolefin dispersions."* (DowNewsroom, 19 October 2013).

Another common theme across sectors is tweets that directly address greenhouse gas, emissions, and/or pollution. These tweets do not acknowledge the role of fossil hydrocarbons in contributing to emissions and pollution. Rather many of these tweets position the hydrocarbon industry as part of the solution to emissions and pollution, or distract from the major source of these problems, such as ExxonMobil's tweet: *"Learn how @ExxonMobil is helping improve tire durability, increase fuel economy and reduce #CO2 emissions"* (ExxonMobil, 9 December 2014). Entities in both the fossil energy and plastic sectors have recently made distinct references to recycling in connection to the Economy and Sustainability topic areas. For example, the ACC tweeted about efforts to develop new forms of plastic recycling,

> *A new project aims to design a process that recycles plastic with near-zero environmental pollution. Learn more about this joint initiative between NAFRA, Charles Darwin University, and the United Arab Emirates University. #flameretardants #circulareconomy* (AmChemistry, 8 December 2021).

Carbon capture is another example of a supposed "solution" supported by the fossil energy sector to distract from the urgent need to transition away from fossil fuels, as in ExxonMobil's tweet:

> *New carbon capture technologies. Fewer methane emissions. Less plastic waste. There are many pathways to a sustainable future and many minds behind the work to achieve that. See some of our team members who are helping make it happen* (ExxonMobil, 6 October 2021).

Finally, one notable theme was consistently present in tweets from all three sectors and across topics: tweets about the unbearable weight of regulatory burdens. Several of the tweets connected regulatory burdens to EPA regulatory efforts or to economic impacts, such as Corteva's tweet regarding potential barriers to agricultural and economic production caused by regulation:

> *We support the Informa Report commissioned by @CropLifeIntl. Farmers need technology & choices to address challenges they face. Delayed import approvals & shifting regulatory timelines & expectations shouldn't be permitted to result in negative impact on #agriculture & economy.* (Corteva, 30 May 2018).

Similarly, API retweeted a concern about the impact of environmental protections on state economy and employment: *"Look out, KY: Stricter #ozone standards could harm state economy, cause #job losses."* (APIenergy, 19 August 2014). These burdens are specifically related to pesticides, food, energy, plastics, and emissions in general such as the ACC's seven tweets in 2022 calling the EPA's Toxic Substances Control Act (TSCA) "misguided", e.g., *"Learn about EPA's misguided policy changes & how they can reverse them in ACC's State of TSCA Report."* (AmChemistry, 11 May 2022).

## 4.4 Coordinated climate obstruction narratives in tweets

The final element of our analysis consisted of examining the major Tweet topics in a modified hybrid version of the Discourses of Climate Delay Framework [35] and climate myths

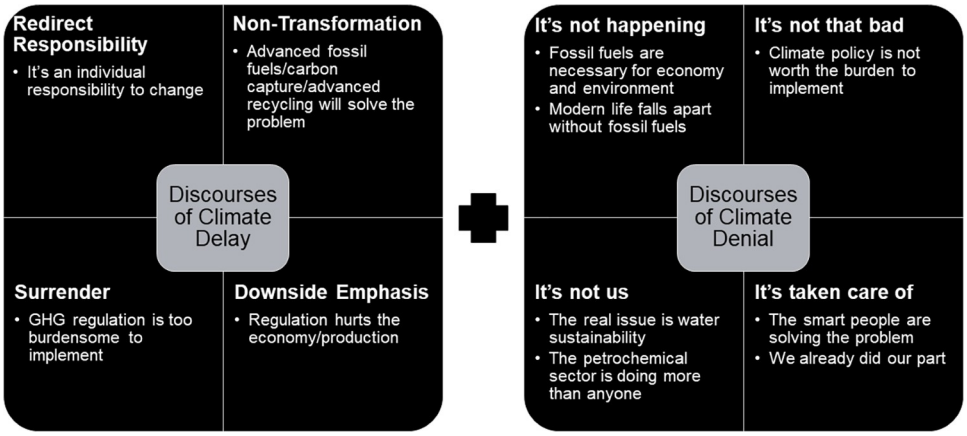


**Fig 7. Example discourses of climate obstruction in petrochemical derivative and fuel organization tweets.**

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framework [90] that we refer to as Discourses of Climate Obstruction (Fig 7). We reviewed the content of the tweets to categorize them as one of the four discourses of climate delay or as outright denial of climate change or the science of climate change (i.e., that climate change is caused by greenhouse gases released by the combustion and processing of fossil fuels).

Redirection is the first type of discourse of climate delay. For example, despite the enormous impact of the petrochemical derivative and fuel sectors on water quality degradation and therefore reduced fresh water availability [97], Dow tweeted about individual responsibility to reduce water use rather than efforts to reduce industrial water use or degradation for Earth Day: *"Which do you choose—Install a low-flow showerhead or wash clothes in cold water? #EarthDay"* (DowNewsroom, 24 April 2014). Another mode of this discourse of delay is displacing responsibility for change to other countries, particularly China. DuPont engaged in this discourse by specifying that China in particular bears responsibility to power itself more sustainably in the tweet: *"Why China must find more sustainable ways to use all energy resources."* (DuPont_News, 13 August 2013).

Non-transformational discourses, on the other hand, propose approaches that do not address the climate crisis at scale. This narrative is very common in the communications of the fossil energy industry. For example, emphasizing recycling diverts efforts away from reducing plastic production and associated emissions toward a short-term approach that extends plastic production. ExxonMobil's interest in extending plastic production is clear in its tweet,

> *We're pioneering advanced recycling of plastics to reduce waste and improve sustainability. One of our chemists, Stephanie Westbrook, shares her experience in leading this initiative.* (ExxonMobil, 20 September 2022).

Using fracked gas maintains existing energy infrastructure and, as a result of methane pipeline leaks, can have a higher carbon forcing effect than coal [98]. As such, ExxonMobil's tweet promoting fracked gas as a less polluting alternative to other fossil energy can be considered an example of supporting non-transformative solutions: *"Natural gas can help fuel our economy while creating less pollution. And ExxonMobil is a pioneer in bringing it to India. #UnexpectedEnergy"* (ExxonMobil, 22 November 2018). Similarly, carbon capture is an approach that has yet to be deployed at scale, but does provide cover for continued petrochemical derivative and fuel production, as API argues: *"Carbon capture, utilization and storage (CCUS) is key to unlocking meaningful emissions reductions across our economy while ensuring access to affordable and reliable energy."* (APIenergy, 26 April 2022).

Many petrochemical derivative and fuel communications, especially those concerning regulation, emphasize the downsides of climate action without acknowledging its importance. For example, the AFB tweeted about the potential harms of greenhouse gas regulation, *"EPA Greenhouse Gas Plan Harmful to Economy, Agriculture"* (FarmBureau, 2 June 2014), as well as about the 'threats' of renewable fuel standards *"RFS proposal threatens U.S. #energy independence, #farmeconomy"* (FarmBureau, 18 July 2016).

The last discourse of climate delay surrendering to the idea that mitigation is not feasible. This is reflected in API's argument that fossil fuel regulations create too much of a burden to be implemented, *"Air-pollution limits proposed by the EPA on the oil & #natgas industry will be "overly burdensome.""* (APIenergy, 2 December 2011).

The other side of climate obstruction is climate denial. Most straightforward among types of denial is the argument that climate change isn't happening at all; that fossil fuels are not causing any problems. API energy has heavily promoted this argument, such as by calling fracked gas necessary to economy and environment, *"Natural gas has fueled a manufacturing rebirth in Pennsylvania. 'This home-grown resource allows Pennsylvania to have both a growing economy and a healthy environment.'"* (APIenergy, 22 June 2020), and by arguing that *"'No one with any common sense would welcome a return to a pre-Industrial Age without oil and gas. Households go unheated, transportation stops, manufacturing is starved, diseases go untreated, the economy nosedives.'"* (APIenergy, 23 February 2018).

The petrochemical sectors have also argued that, while climate change may be occurring, it is not severe enough to warrant a policy response. The ACC retweeted about this approach, *"Oil, mining groups urge House to curtail EPA climate rules in CR"* (AmChemistry, 17 February 2011).

Another form of denial is that perhaps climate change is happening, but petrochemical derivative and fuel producers are certainly not responsible, and are even part of the solution. This approach is echoed across the sectors as the organizations provide cover to each other. For example, Dow praises its partnership with GE for sustainable fossil fuel extraction in this tweet: *"Partnering w/ @GE_PowerWater @encana to ensure #sustainable #watermanagement in #shale oil&gas extraction @ Neptune Water Treatment Facility"* (DowNewsroom, 3 November 2015). Similarly, the ACC awarded ExxonMobil "Responsible Care Company of the Year" in 2009 (and again in 2022 and 2023 [99]) despite a clear record of harm to human, social, and environmental health [43, 44, 100],

> *Congrats @exxonmobil, recipient of ACC's #ResponsibleCare [Registered Trademark] Company of the Year Award, for initiatives to improve #EHSS performance, drive emissions reductions toward #NetZero & inspire local communities & employees to practice sustainability* (AmChemistry, 30 April 2009).

Finally, API tweeted that fossil fuel infrastructure is "safe" and "environmentally friendly": *"#Keystone XL is a 'job-creating, safe, environmentally friendly pipeline plan.' #keystonetruth #climatetest"* (APIenergy, 2 December 2013).

The last form of denial is dismissal; the argument that there is no climate crisis because human ingenuity has and will continue to resolve any problems. This may look like recognizing a sustainability challenge in the petrochemical sectors, but arguing that the problem is taken care of, as in API's tweet:

> *Since its inception, The Environmental Partnership has worked with industry leaders to develop energy solutions for a safe and sustainable future. Learn how companies are making progress toward environmental goals in the 2020 annual report* (APIenergy, 16 July 2020).

This form of denial can also look like "the smart people are on it", such as in Dow's tweet displacing climate responsibility to MIT engineering: *"Collaborative approaches like @MITEngineering's Climate and Sustainability Consortium are how we will achieve our shared vision for a sustainable future. #SeekTogether"* (DowNewsroom, 9 April 2012)

Policy obstruction in the tweets is not limited to climate policy. Other public health concerns driven by petrochemical derivative and fuel production and use are also undermined. For example, the trade association for plastics refuted established understanding of the health risks of BPA, claiming that 'it's not us':

> *What does the science tell us about BPA and cancer risk? Numerous scientific studies have found that BPA has little potential to cause health effects. Learn more about what the science says about BPA here.* (AmChemistry, 21 November 2022).

Similarly, the agrichemical trade association pushed back against 2014 EPA regulations protecting water by emphasizing the downside, *"Enjoying your locally grown produce*? *Don't let the EPA put your local farmers out of business"* (FarmBureau, 6 June 2014). FMC's tweet about individual responsibility for managing plastic pollution is an example of redirection, a common type of corporate discourse that attempts to undermine corporate responsibility for environmental issues by shifting blame from the entities that produce, market, and industrially use a toxic material to individuals who in many cases do not have an alternative option for consumption:

> *#EarthDay Tip 2: Re:use (bags, containers and utensils). Plastic pollution is clogging our waterways, killing and injuring wildlife and endangering our health and safety, so try to limit your use of plastic items and opt for sustainable products.* (FMCCorp, 24 April 2018).

This tweet is notable because FMC does not produce plastics itself, so the company is not redirecting attention away from its own practices, but that of the plastics industry.

## 5. Discussion

This analysis of the social media interactions of three petrochemical derivative and fuel sectors provides evidence of fossil energy corporations' hegemonic and coordinated climate obstruction efforts, reinforcing findings from previous research. Investigative research has uncovered many different activities carried out by fossil energy companies that have the effect of undermining climate action [21, 43, 44]. These include donating to congressional campaigns, lobbying policymakers, funding research to cast doubt on climate science, and reframing public discourse toward favorable perspectives about fossil energy. Claims have also been made that fossil energy companies have invested in influencing judges and law students and grassroots political interest groups to resist government regulation in local communities and promote their interests [6]. There have also been suggestions that companies have placed media professionals to support fossil energy in "both sides" coverage and sent educational pamphlets to k-12 schools to teach children about the benefits of fossil hydrocarbons and the free market [6, 18, 22, 101, 102]. Evidence of each of these hegemony-reinforcing activities are apparent within the tweets and social media networks of not only the energy industry, but also the plastics and agrichemicals industry.

An important contextual observation to mention (an observation that does not require Twitter analysis) is the widespread and frequent corporate consolidation and dissolution among US petrochemical derivative and fuel enterprises. Relationships among these corporations involve multiple interconnections. For example, DowDupont's merger and break

horizontally integrated the two largest plastics corporations in the US and resulted in the two largest plastics corporations (Dow and Dupont) and the largest agrichemical corporation (Corteva). Both ExxonMobil and Chevron have branches that work in plastic production, as well, exemplifying vertical integration in the versatile fossil fuel-hydrocarbon supply chain. Each of the nine central organizations was not only connected to other actors in their own sectors, but interacted with the actors from other sectors and shared mention relationships with other sectors, which shows the close interconnection across sectors. At the center of these nine organizations is the ACC, which shows the intermediary role of plastic chemical corporations in petrochemical derivative and fuel production.

Also among the most notable trends in the dataset, it is important to highlight the prevalence of arguments by each sector about how their products benefit society. This positive messaging, which was widespread and prominent in all of the twitter accounts, was coupled with a frequently mentioned message about concern with regulatory burdens. Many of the tweets also mentioned economic or societal benefits from one of the other fossil fuel-reliant sectors or referenced the benefits to their own industry from production in one of the other sectors. Examples of this include general discussion about the value of plastics and recycling in the food industry, or the benefits of fracked ("natural") gas in the plastics industry. All three sectors mention pollution, emissions, and/or greenhouse gases in the context of either promoting their role in solving these problem or fighting against regulation in these sectors.

Despite public declarations of "green" goals and commitments to net-zero, analysis of the corporate production and sales strategies of fossil energy corporations–including Chevron and ExxonMobil–reveal intentions to continue to increase petrochemical production [103]. Aligned with this, this analysis shows that organizations in all three sectors use Twitter to promote their charitable and educational efforts related to environmental actions to promote a positive image demonstrating environmentally responsibility. Many of the initiatives that they promote appear to either minimally address the social and environmental damage caused by the organization, or to actively undermine and reshape public understanding of these damages.

Using our integrated ***discourses of climate obstruction*** framework, we identify how many of these tweets are obstructive, suggesting the claims may have been shared with the intention of stopping, slowing, or reversing climate policy or action. Combined with the high engagement of the petrochemical derivative and fuel sectors with government regulatory, policy, and political entities in energy and environment in particular, this suggests strategic attempts to undermine and subvert climate policy through social media. All three sectors, for example, have heavily supported fracking and the buildout of fracked gas infrastructure on social media. The industries have argued that fracked gas can act as a "bridge fuel" because it is better for the environment than other fossil fuel energies (e.g., oil and coal), however the high point source pollution and radiative forcing of methane gas during flaring and from leaky pipelines have shown that fracking may have a worse impact on climate change than coal [98].

This raises another major implication of our analyses. Policy obstruction may be interpreted as a specifically negative intervention, like the tweets promoting dismantling or weakening regulations. However, analysis of the content of these tweets shows that positive interactions that promote uncritical views of the fossil hydrocarbon sectors are also a form of climate policy obstruction. Conveying an overly positive image by making misleading claims is increasingly recognized as greenwashing [104, 105]. Recent research has defined more clearly how to identify greenwashing [106], and many of the tweets we analyzed could be defined as greenwashing. Most of the tweets in this dataset were positive with a strong can-do attitude, i.e. very few tweets could be categorized as defeatist, surrendering, or giving up. Many of the tweets characterized as emphasizing downsides of climate action were in fact

emphasizing upsides of climate inaction. This is likely because public relations strategies tend to encourage positive portrayals of corporate–social interactions.

Limitations to the methods of data collection and analysis in this study include the short length of individual tweets. Tweets are limited to 140 characters until 2017 and have remained limited through 2023, which reduces nuance that can be included in a single tweet or retweet simplifying the messaging. Still, tweets are a valuable communication to analyze because they represent an intentional message to the public on an open platform. This analysis is also limited by our examination of messages tweeted by a single, US-based twitter account per organization, when each organization has multiple Twitter handles by location, product, charity efforts, et cetera. We selected the primary organizational handle to consistently evaluate the communication from the central Twitter voice of each organization. This has likely resulted, however, in an overemphasis on American communications in our network and content analyses, meaning that further research examining a broader geographical range of networks and communications may reveal different trends. A further limitation is that the selected Twitter accounts have not been active for the same amount of time or used at the same frequency. Whereas the ACC account first tweeted in December 2008, Corteva's first tweet was not until February 2018, nearly ten years later. Unsurprisingly therefore, Corteva has the fewest total number tweets at 167 tweets, whereas API has tweeted the most at 41,393 tweets. Because of the difference in number of tweets, agrichemicals are relatively underrepresented in the dataset and fossil energy organizations are overrepresented. This imbalance was overcome, however, because we conducted the text and network analyses by sector, so we were able to compare three sets of discourse themes and mentions networks rather than directly comparing each Twitter handle. The network analysis was not standardized against a comparison network because this analysis seeks to determine the presence, nature, and impact of the fossil hydrocarbon social media network as opposed to its relative size or strength of connection.

Another limitation of this analysis is due to corporate consolidation and dissolution. Because Dow, DuPont, and Corteva were at one point the same organization, similarities in messaging and networks among those entities during that period can be attributed to shared corporate leadership, rather than a broader collaboration. However, the organizations have been distinct for the majority of the analysis period, and our sectoral analysis approach was applied to reveal themes in mentions and discourse across the three sectors rather than within the three sectors. Additionally, this analysis was limited to one primary social media handle per corporation to maintain scope, despite the many additional handles run by several of the organizations studied.

Finally, it is important to note that while Twitter was an active, stable platform during the period of study, the 2023 rebranding of the platform as X and other corporate changes have altered the way the platform is being used. The new ownership that took over in 2022 shifted the moderation policy and reinstated some formerly banned accounts which has changed the culture, led to a decline in ad revenue and decreased user activity as users have disengaged with some moving to competing social media platforms [107, 108].

## 6. Conclusions

This analysis of the networks of mentioned accounts and tweet contents of the Twitter handles of nine organizations in the three dominant US fossil hydrocarbon sectors shows that petrochemical derivative and fuel corporations are closely related, they interact frequently with each other and with policymakers on social media, and many of the messages they share and reinforce could be categorized as climate obstruction. We propose and apply a hybrid Discourses of Climate Obstruction framework to understand the ways that networked organizations are

contributing to climate obstruction individually and amplifying similar messages from other organizations within the hydrocarbon sectors. Ultimately, our analysis reveals that these organizations are connected on social media not only to other industries in the same sector, e.g., Chevron to the other fossil energy organizations, ExxonMobil and the American Petroleum Institute, but also with organizations from other sectors, e.g., Chevron is linked to plastics organizations and agrichemical organizations. Our analysis of the tweet content shows cross-cutting and similar themes framed across the sectors and how these tweets reflect the nature of advocacy on these topics by each organization. These connections on social media represent one way organizations within the fossil hydrocarbon industries can collectively foster fossil fuel hegemony; reinforcing climate obstruction and contributing to climate delay and denial by connecting industry goals to individual interests and suppressing need for transformational climate policy. Research highlighting that social media communications are constructed to identify individuals to the cultural and political objectives of the fossil fuel industry may help social media users to receive these messages more critically, potentially ultimately contributing to 'dislocating' the fossil fuel hegemony [33].

Although journalistic reporting has begun to describe some of the ways that these sectors are mutually dependent on petrochemical production, the climate policy and obstruction literatures so far have not studied the connections between fossil energy corporations, plastics, and agrichemicals and the ways that these three sectors are collaboratively obstructing efforts to reduce the extraction, processing, and consumption of fossil-derived hydrocarbons. Based on our findings, we argue that, to better understand the lack of effective and ambitious climate policy, particularly the slow pace of fossil fuel phaseout policy, researchers need to expand analysis beyond fossil energy producers to identify how the larger petrochemical industry contributes to reinforcing fossil fuel political and cultural power. Fossil energy needs to be considered part of a larger pantheon of petrochemical products that collectively contribute to environmental degradation, human health harms, and undemocratic political reforms through aggressively pro-corporate political lobbying and the connection of individual identities with fossil fuel interests. The refusal of hydrocarbon industries to transform away from fossil fuel extraction, compounded by communication strategies that may contribute to narratives of climate obstruction, underscores the importance of supply side regulation of hydrocarbon production for any end use, not just fossil energy, as well as "multiscalar activism" that reflects the collaboration among fossil hydrocarbon industries in coordinated action beyond one issue or context [109, 110].

This study contributes to a growing literature that reveals coordination and cooperation among fossil fuel interests around the world [30, 111, 112]. As calls to phaseout fossil energy become more salient and the need for fossil fuel regulation becomes more urgent, more research is needed to effectively respond to the power and influence of petrochemical industries and their climate obstruction efforts.

## Supporting information

**S1 Data. Full List of referenced tweets.**
(DOCX)

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