Tracing procedural justice at UNFCCC conferences through side events and interest group dynamics

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Tracing procedural justice at UNFCCC conferences through side events and interest group dynamics

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Abstract

Procedural justice is essential in climate negotiation spaces to ensure inclusivity and transparency in a global challenge. However, annual Conference of the Parties (COP) meetings of the United Nations Framework Convention on Climate Change (UNFCCC) are increasing in size and complexity, which makes discourse and organisational relationships more uneven and harder to understand. Here, we analyse UNFCCC COP side events during 2003–2023 using topic modelling to understand the evolution of discourse and topic framing. We use participant nomination data to investigate how incumbent business interest groups access COPs and evaluate the relationships between side event organisers and speakers. Among energy side events, we identified growing interests in fossil fuels, marked by a uniquely collaborative organisation network of mainly NGOs. Incumbent corporations gain access to COPs through NGOs in developed countries and through governments in developing countries, with limited presence leading UNFCCC side events. We show the importance of systematically tracing and considering processes at COP as a first step to improving procedural justice at the highest level of global climate governance.

Main

Since its adoption in 1992, the United Nations Framework Convention on Climate Change (UNFCCC) has brought the international community together to negotiate global commitments and actions to combat climate change, particularly at its annual Conference of Parties (COP). The UNFCCC process is designed to give all countries that are signatories (*i.e.,* Parties) "common but differentiated responsibilities"[1] in climate action regardless of their size or economic capacity. Managed by the UNFCCC secretariat, accreditation to the process grants eligible non-state participants (*i.e.,* Observers) from other UN agencies, intergovernmental organisations (IGOs), and non-governmental organisations (NGOs) access to official sessions. These accredited organisations may subsequently freely nominate the members on their delegations. Although non-state actors do not directly participate in decision-making in final negotiation texts, they voluntarily contribute to climate progress alongside state-led initiatives, by sharing expertise, providing oversight for Parties' progress, and facilitating ambition through a hybrid multilateral governance structure[2–4].

Access to the site of the intergovernmental negotiations is limited but can shape broader discourse and influence actual negotiations through side events, pavilion events, or informal meetings. Observers are not always privy to formal negotiations but can contribute to decisions in informal ways[5]. Side events have been meaningful for knowledge transfer and capacity building, thereby increasing the input legitimacy and acceptance of the process[6]. They have historically mirrored 60–75% of topics discussed in formal negotiations[7] and introduced issues before they became negotiation items[6]. As such, side events could act as a forum to improve representation and procedural justice, broadening non-state actor engagement[5] and ensuring equitable "access to decision-making processes" of stakeholders[8]. Business interest groups are uniquely able to activate and grow into dominance quickly in transnational climate governance[9], through hedging strategies that engage with least-cost policy design[10]. Despite media concerns about the prevalence of fossil fuel lobbyists at COP28 in Dubai[10], how they access, engage with discourse or shape negotiations is poorly understood. While participant surveys[6,12] and qualitative analyses[13,14] have been undertaken, the growing size and complexity of COPs in recent years[2] require a more quantitative and systematic analysis of actor networks to reveal the emerging influence dynamics.

Such understanding can be facilitated by recent developments in machine learning and topic modelling in synthesising text-based climate change information including big literature[15,16], social media sentiment on carbon dioxide removal[17], and fossil fuel company climate change communications[18]. Given the importance of international networks underpinning multilateral environmental agreements, social network analysis has been applied previously to explore the coalition[19] and connectivity patterns[20] in environmental treaties, collaborations among UN entities on biodiversity[21], the author network of an IPCC report[22], and the role of the UNFCCC secretariat in non-state actor networks on Twitter[23]. However, our understanding of the relationships across non-state actors, particularly business interest groups such as fossil fuels, and their engagement with the discourse at international climate conferences remains limited. As governance challenges become more diverse and complex, it is important to identify key organisations at COP, analyse their network dynamics, and unravel their role in shaping the discourse.

This work is a first attempt to quantitatively understand the relationships and discourse of non-state actors at COPs through analysing their networks of topics (what) and non-state actors (who). Firstly, we conduct topic modelling on side events from COP9 (2003) to COP28 (2023) using natural language processing. To explore the evolution of side event topics over time, we analyse the frequency of topic occurrence and the patterns of topic framing focusing on frequent topics including, energy, forest management, and food. Secondly, using data on delegates' affiliations and their nominators from COP28, we map a bipartite network of nominated business interest groups in energy and food to identify their pathways to access COP28 and the relationships between their nominators. Finally, we identify the relationships of these business interest group affiliates within the networks of side event co-host organisations over time and the networks of COP28 side event speaker organisations to infer their engagement in the process. Overall, we establish a quantitative framework (Extended Data Fig. 1) to trace the growingly complex network of relationships within the UNFCCC process, highlighting areas of further justice discussions and improvements.

The evolution of side events over time

The evolution of topics at side events can mirror the attention paid to different areas of climate change during the negotiations and broadly at COPs. From the 4,688 side events during 2003–2023, we identified 63 distinct topics, with forest management (343 events), renewable energy (221 events), and food and agriculture systems (212 events) being the three most common over time (Fig. 1). Several other energy-related topics emerged in nearby clusters, including fossil fuels, bioenergy, nuclear energy, and energy poverty. The large number of energy events and breadth of discussions led to detailed categorisation of energy topics, and we considered them together. Food and agriculture system topics have grown to over 5% of events recently, while forest management topics halved by 2023 from over 10% in the 2010s. Energy topics have fluctuated around 5–10% throughout. Bigram text analysis showed how event topics have experienced shifts in priorities and framing.

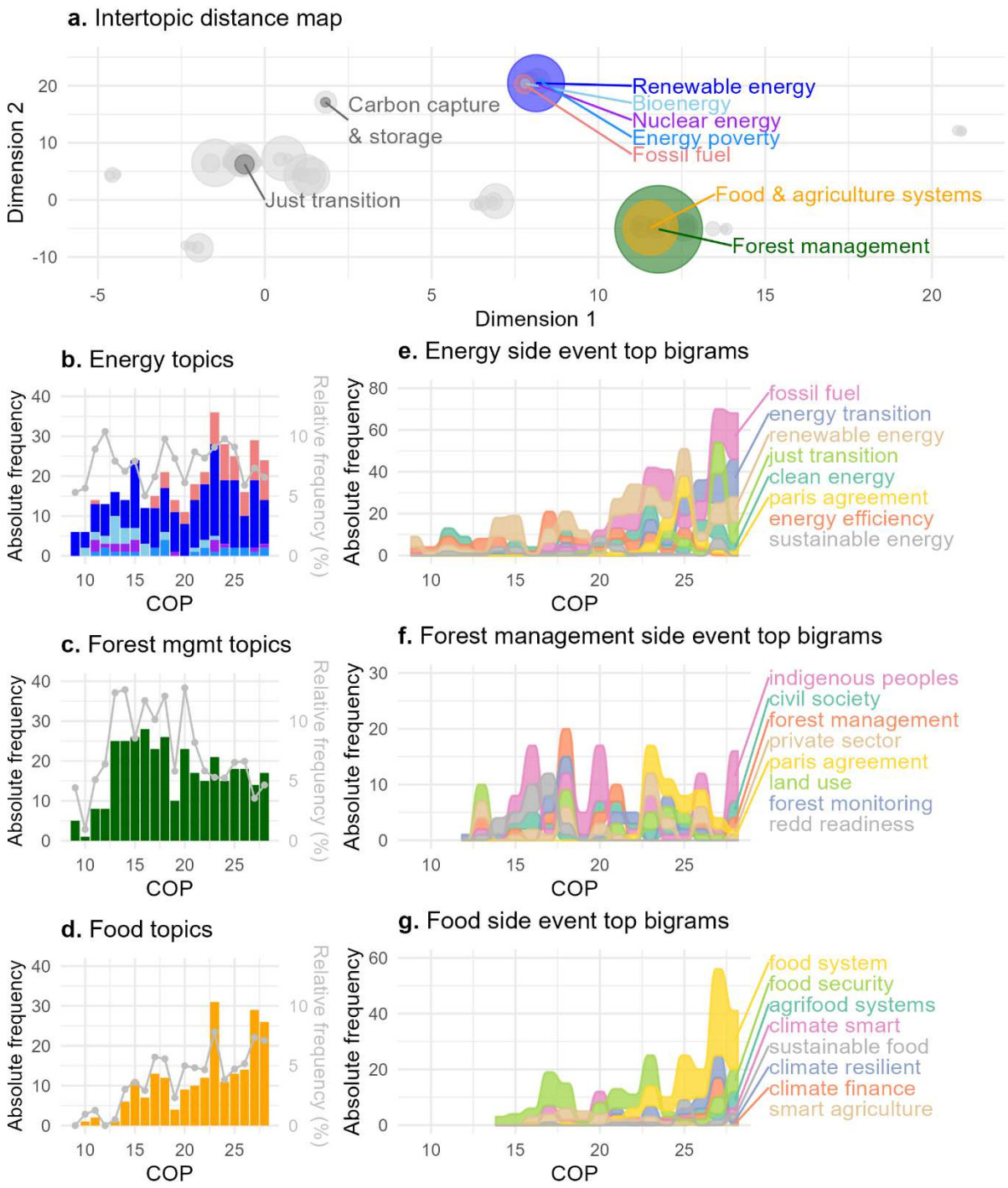

Fig. 1 | Summary of UNFCCC COP side events topics from 2003 to 2023. The topics are from machine-learning pre-trained topic modelling on side event titles and descriptions reported to the UNFCCC (see Methods). **a**, The inter-topic distance map visualises topics using the two-dimensional projection reduced through UMAP (see Methods). The sizes of the bubbles represent the number of events assigned to the topic. **b-d**, The topic occurrence of energy (**b**), forest management (**c**), and food (**d**) side events over time in absolute and relative terms. The relative frequency was normalised to the number of side events in each year. **e-g**, The alluvial plots of top eight bigrams for energy (**e**), forest management (**f**), and food (**g**) side events over time. The terms without line connections are prominent overall but absent in COP28. COP, conference of parties. Forest mgmt, forest management.

Energy side events two decades prior focused on broader terms such as clean, renewable, and efficient energy, with renewable energy being consistently prominent throughout. The sustained political interest was codified as the First Global Stocktake (COP28) calls on Parties to triple the global renewable energy capacity by 2030[24]. Early attention on energy access declined over the years. The discourse around phasing out fossil fuels was side-lined in the early years of the UNFCCC process[25] despite fossil fuels contributing to 64% of global anthropogenic greenhouse gas emissions in 2019[26]. As criticism arose towards the dominant role of high-polluting nations and corporations[27], discussions about fossil fuels have increased to nearly half of all energy events since COP17 (2011). This growing discourse mirrors recent developments in anti-fossil fuel norms[14], where the Glasgow Climate Pact from COP26 (2021) addressed the transition away from fossil fuels for the first time[28]. In addition to renewable and nuclear energy, carbon capture and storage (CCS) and hydrogen were listed as crucial technologies in the First Global Stocktake[24], endorsed by oil and gas companies[13], in part due to the transferable knowledge from their core business[29]. As such, the side event discourse on CCS is more closely aligned with events around carbon markets and emission trading, rather than the energy system.

Just transition became more prominently mentioned in energy discussions since COP21 (2015) when the landmark Paris Agreement put the issue high on its preamble agenda [30]. The discourse around just transition included global fossil fuel extraction phase-out guided by justice principles, North-South cooperation, and participatory dialogues in renewable energy projects. Topic modelling also showed a unique cluster on just transition not exclusively connected to the energy system. These events covered discussions around the Just Transition Work Programme, labour unions, and jobs, closely aligned with the original concept of just transition[31]. This growing recognition of the intersectionality of just transition discussions at side events was mirrored by similar evolutions on negotiation texts[32].

The interconnected topics in forest management and food and agriculture have also become more intersectional. Introduced at COP11 (2005), forest management discussions through reducing emissions from deforestation and forest degradation (REDD+) initially focused on readiness and monitoring (Fig. 1). Since its onset, governance[33] and land tenure[34] challenges have led to opposition and controversies. Throughout the implementation, its negative impacts on local livelihood and socio-cultural norm[35] were addressed in the recent discourse centring on the role of Indigenous Peoples, civil society, and private sectors. The food-related discourse has evolved from solely focusing on food

security to a broader perspective centred around food systems, resiliency, and finance. Globalisation has integrated food systems across regions and countries, but the associated greenhouse gas emissions have surged, largely due to expanded trade, transportation[36], processing[37], and packaging[38]. Consequently, the growing prevalence of food-related discussions at COPs, coupled with a narrative transformation, reflects global recognition of the key role of food systems in climate change and highlights the importance of system-wide strategies to mitigate impacts while safeguarding food security[39]. Notably, the meat and dairy industry was absent throughout the discourse despite contributing to a fifth of global greenhouse gasses around 2010[40]. Addressing meat consumption was found socially and politically contentious by many NGOs[41], as some countries heavily rely on livestock production for food security and economic stability[42]. This nuance may explain the absence of advocacy and shows the need for further discourse.

Paths of interest group access to COP28

While investigating procedural justice it is crucial to understand who is represented in these discussions, especially high-polluting incumbent interest groups in energy and food. Engagement with policy regulation is central to business strategies[10]. The historical role of incumbent businesses (especially oil and gas) in undermining climate progress has been criticised[13,43,44]. Using new data on participant affiliations at COP28, we found 380 delegates (0.5% of all participants) representing the oil and gas industry and 88 delegates (0.1%) in the meat and dairy industry. The nomination mechanisms for these industry interest groups highlighted deeper connections with governments in developing countries and with business NGOs in developed countries (Fig. 2). The number of delegates from oil and gas companies identified here is much smaller than prior estimates of fossil fuel lobbyists[11] since our analysis excludes members of NGOs that may be affiliated with oil and gas interests. The breadth of oil and gas companies present at COP28 confirms the importance of engaging with the UNFCCC process for the industry[13]. Fossil fuel companies have proactively participated in the development of energy outlooks and scenarios[43] which introduce their viewpoints and quantitative assumptions in the grey literature. Conversely, meat and dairy companies have mostly focused their decarbonisation targets on energy consumption rather than addressing their responsibilities in reducing methane emissions from the core of their practice[44].

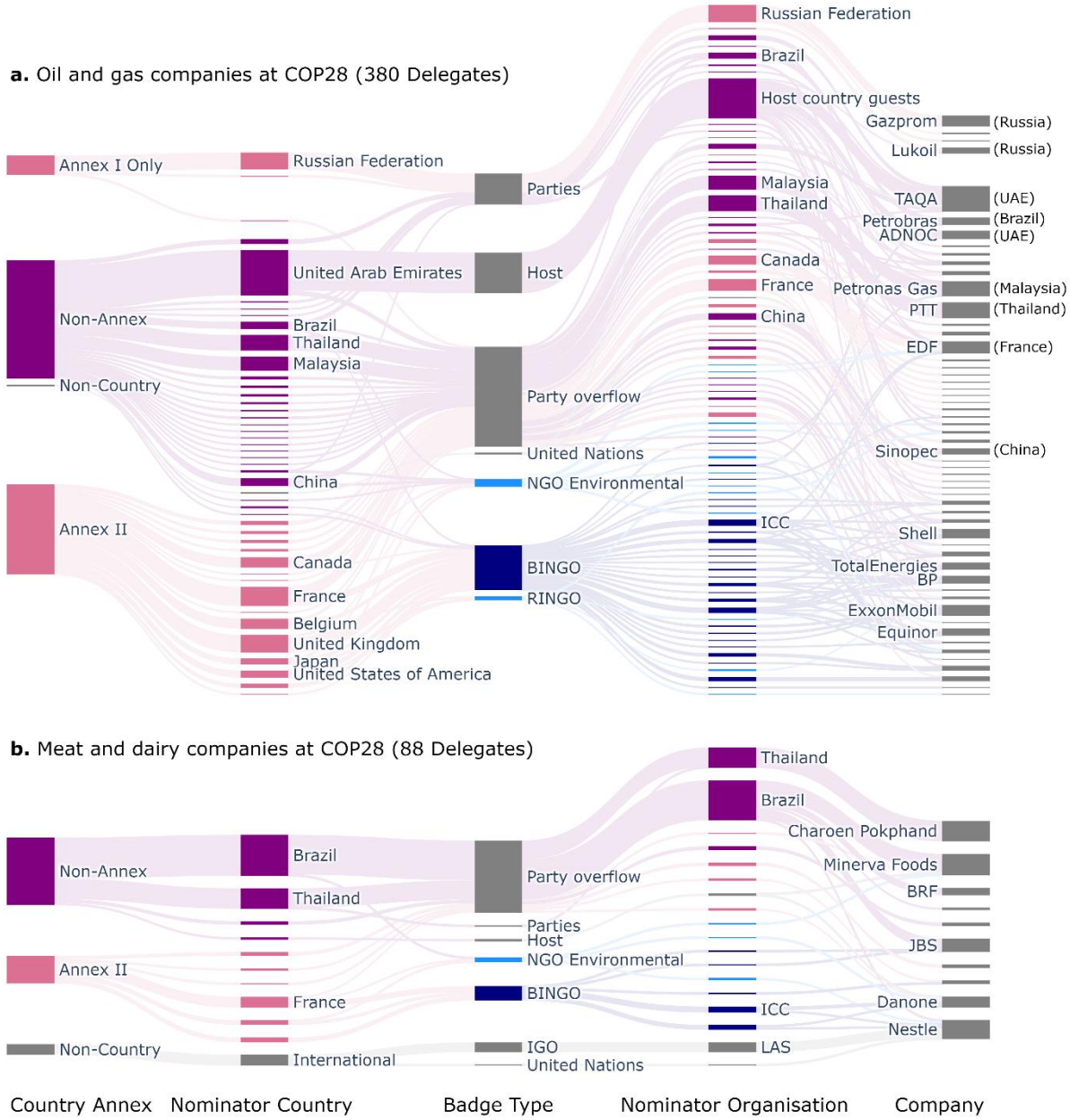

Fig. 2 | Sankey diagrams representing the nominators and interest group delegates at COP28. **a–b**, The interest groups include the oil and gas industry (**a**) and the meat and dairy industry (**b**). The companies are selected based on top market capitalisations in each industry. The delegates are identified through their primary affiliations reported to the UNFCCC participant list. The country affiliations of NGOs are based on their headquarters locations. The oil and gas nominators and companies labelled have more than 10 delegates; the meat and dairy labels represent more than 5 delegates. NGO, non-governmental organisation. BINGO, Business and Industry NGO; RINGO, Research and Independent NGO. ICC, International Chamber of Commerce. TAQA, Abu Dhabi National Energy Company. ADNOC, Abu Dhabi National Oil Company. EDF, Électricité de France S.A.

At COP28, the host country United Arab Emirates (UAE) nominated the highest number of delegates from oil and gas companies, mainly comprising representatives from state-owned businesses. National oil companies were mostly nominated through Parties and Party overflows in non-Annex (developing) countries and a considerable number of Annex

I (OECD and transitioning economies) countries (Russia, Canada, and France)[13], indicating the close relationships between the state-owned companies and governments in these countries. International oil companies were more connected with varied business and industry NGOs in Annex II countries. Such connections reflect an internationally concerted effort in advocacy, exemplified by a controversial leaked letter by the Organization of the Petroleum Exporting Countries (OPEC) that urges members "proactively reject any text or formula that targets energy, i.e. fossil fuels, rather than emissions"[45]. The meat and dairy companies showed different geographical connections with governments in Brazil and Thailand. Identifying the common nominations across nominators also highlights the shared interests of these nominators, which highlights clusters of interests and positions. Connections amongst these nominators through shared nominations can be traced from one-mode projections (Fig. 3) to infer the influence of organisations.

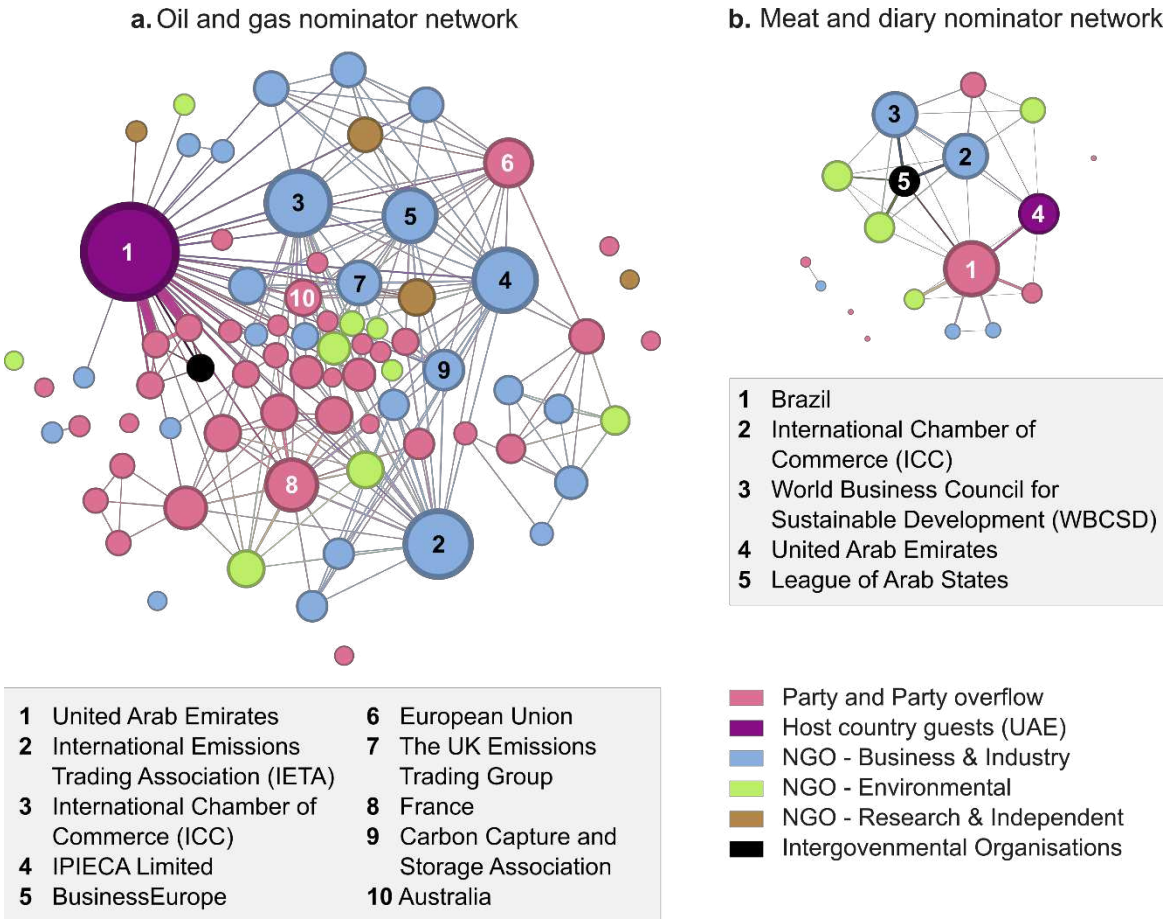

Fig. 3 | One-mode projections for nominators of interest group delegates at COP28. The connections across NGOs and parties are projected from their co-nomination of companies. Each edge is weighted to the number of shared company nominations (*e.g.,* Shell and TotalEnergies) between two nominators (*e.g.,* UAE and ICC) which indicates some shared interests. **a-b**, Networks for nominators of oil and gas industry delegates (**a**) and meat and dairy industry delegates (**b**) are colour-coded by badge type. Node size represents the degree (number of edges) of a node within each network. The sizes are not proportional between networks. Nodes with the highest degree scores are labelled. The oil and gas network has a network density of 7.7% and the meat and dairy network has a network density of 22.2% relative to all possible connections. The network graphs are generated using the Force Atlas 2 algorithm with Gephi[46]. IPIECA, International Petroleum Industry Environmental Conservation Association.

The host country UAE emerged as the most connected node for both degree and eigenvector centrality (Supplementary Table 3), indicating a high number of mutual nominations of oil and gas companies with other influential organisations. This was followed by prominent business and industry NGOs. Oil and gas delegates were less than 10% of ICC and IETA's broadly themed business delegation while taking up most of IPIECA's delegation. France and the EU emerged as the most prominent parties, where France shared connections with various countries and NGOs and the EU shared connections with several business and industry NGOs like Business Europe, ICC, and IPIECA. The prevalence of European trade associations connected with Europe-based international oil companies

is aligned with previous research recognising their proactive attitudes towards climate change compared to their American counterparts[13,47]. The meat and dairy network contains fewer actors with a high degree of connectedness, which indicates that many of these entities are nominating the same meat and dairy companies. Brazil scored highest in degree and eigenvector centrality (Supplementary Table 4), indicating its strong shared interest with other influential nominators. Notably, Brazil's interests converge with other prominent nominators such as the ICC and the World Business Council for Sustainable Development.

Networks of organisations within discourse topics

To understand the thematic landscape through organisational leadership, we investigated the organisers of side events by country Annex and constituency, using energy-related side events as a case study. Environmental and research NGOs in developed countries hosted more energy-related side events (Fig. 4). Business NGOs have been interested in the development of energy technologies. Party representatives were more involved in hosting side events in earlier COPs, but engagement is now more dispersed. Limited representation was found with non-Annex countries (25% of COP28 energy events, cf. 78% of all Parties and 83% of the global population) and constituencies including Indigenous Peoples, women, and youth (less than 5%), although this has improved in the last two decades. The over-representation of high-income country groups may be due to the higher organisational capacity to coordinate events, but efforts to increase thought leadership from developing country organisations could improve procedural justice.

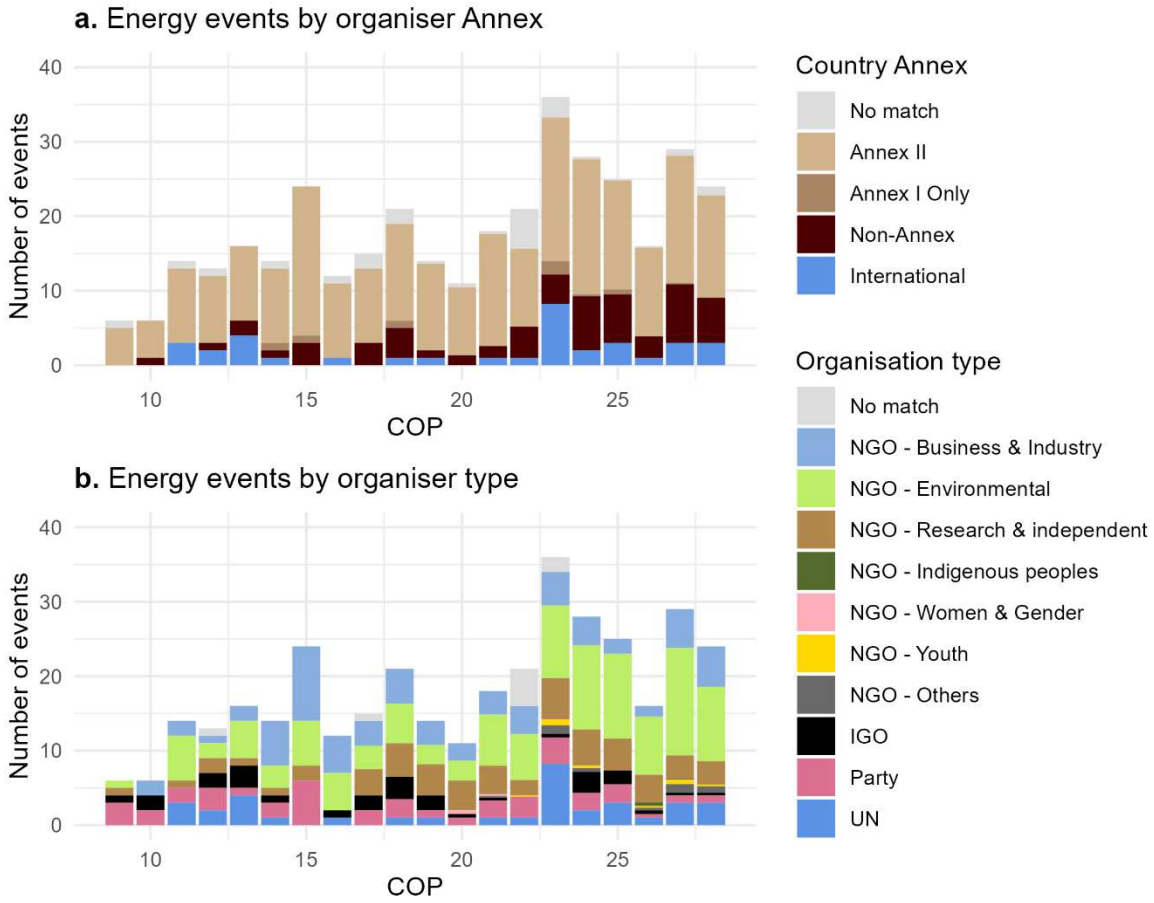

Fig. 4 | Side event organisers attributed to their country affiliations and constituencies. **a**, Energy side events by country affiliation. **b**, Energy side events by constituency. NGO, non-governmental organisation. IGO, inter-governmental organisations. UN, United Nations, related organisations, and specialised agencies. Sections labelled no match refer to organisations marked in the side events record but are not on the officially accepted organisation list.

While such attribution can showcase the magnitude of organisations' engagement on a topic discourse, questions remain regarding the relationships between organisations and their transitive influence within the network. Here, we used social network analysis to investigate both the organisations of high influence and those affiliated with business interests through nomination. Side event organising entities were represented as nodes, with events depicted as edges. Due to the growing number of COP side event applications, the Secretariat of the UNFCCC may administratively combine events to accommodate more organisations. As such, we manually extracted the organisations from invited speakers and panellists at COP28 energy events to contextualise the results.

The energy side event co-hosts were sparsely connected, while events on fossil fuel phase-out shared more dense connections and central positions (Fig. 5). Although the dataset dates to COP9, co-hosting patterns in energy events only occurred since COP17.

The eigenvector centrality measures showed that the Center for Biological Diversity (CBD) and Oil Change International (OCI) were some of the most influential organisations in the network. OCI has the highest betweenness centrality, indicating bridge-builder characteristics. Since COP21, these NGOs and their collaborators have consistently organised joint events on fossil fuel phase-out, representing a highly dense and central part of the network. Although the discourse on fossil fuel only appeared in the past decade, the organisations were more cooperative and potentially shared a more unified message, putting pressure on ambition[48]. The organisers of renewable energy events were more scattered, with the World Future Council building the most connections within the topic. The International Network for Sustainable Energy was central within the sub-network of energy poverty-related events. The renewable energy and fossil fuel networks shared some overlaps, but the nuclear network demonstrated distinct organisers. Over time, oil and gas affiliate organisations represented 7% of the energy side event organiser network, showed low centrality metrics, and were located far from the centre. Finland and Norway were the only two affiliated Parties peripherally linked with the fossil fuel event network through fossil fuel subsidy reform discussions. The International Hydropower Association organised several renewable energy events, although they nominated participants from the Adani Group, the biggest Indian conglomerate with businesses in mining and natural gas. The dynamic at UNFCCC energy side events shows a level of disconnect between prominent fossil fuel interest and broader non-state actor discourse, which raises questions about whether and how fossil fuel companies should engage in future energy systems[49].

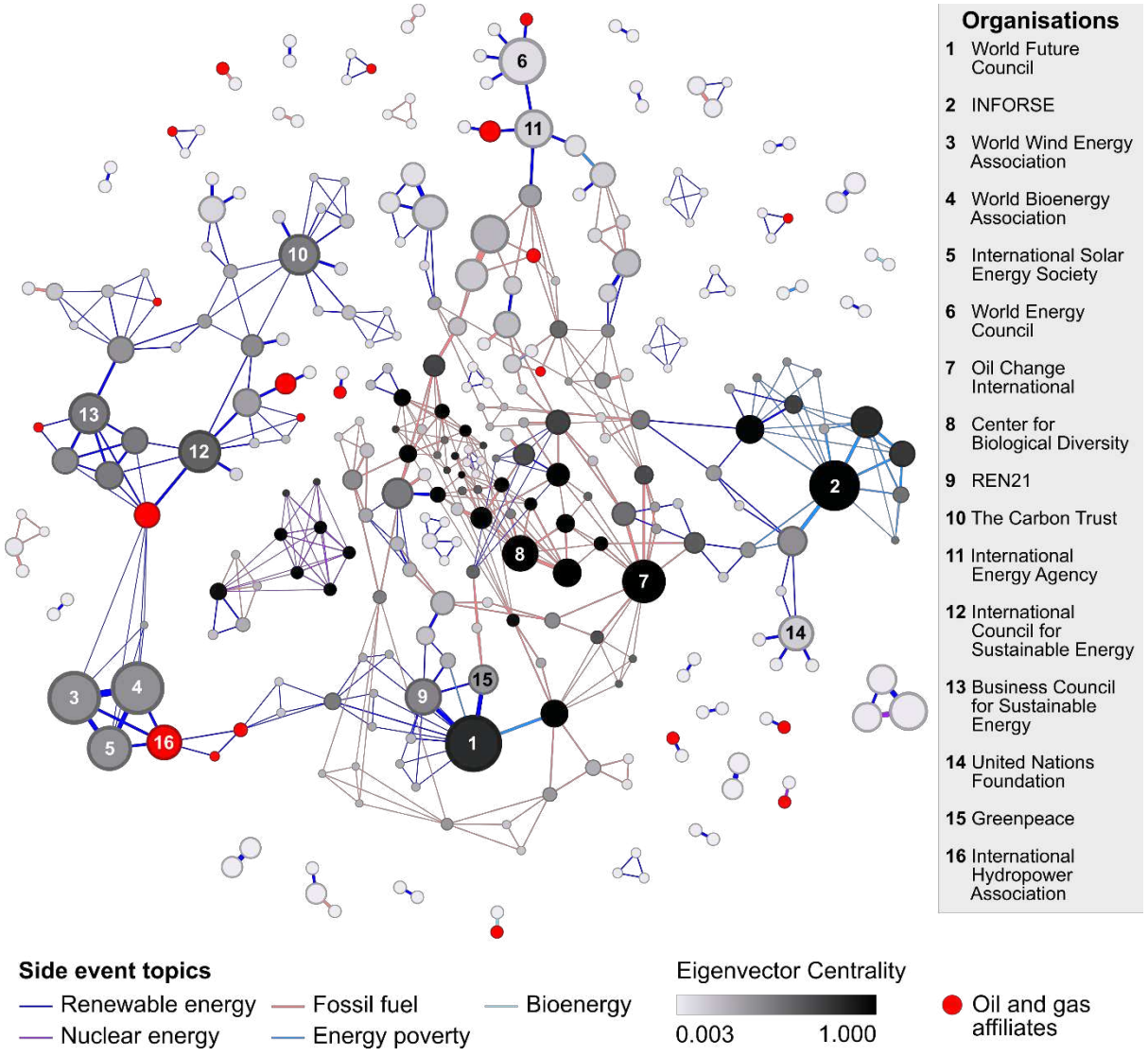

Fig. 5 | Co-host organisation networks for energy side events during COP17-28. Node sizes represent weighted degrees. The co-host network has a network density of 1.1%, representing completed connections relative to all possible ones. Edge colour represents the topic of side events, and the lightness of grey nodes represents the eigenvector centrality, except for red which represents oil and gas affiliates. INFORSE, International Network for Sustainable Energy.

Although side event organisation is restricted to organisations acknowledged by the UNFCCC system, invited speakers and panellists are extended to companies, international funds, and civil society campaigns (Fig. 6). At COP28, the International Renewable Energy Agency (IRENA) was the most prominent speaker among renewable energy events, followed by the Climate Action Network International (CAN) covering both renewable energy and fossil fuels. Fossil fuel events invited more civil society campaigns, including Don't Gas Africa and the Fossil Fuel Non-Proliferation Treaty Initiative, both of which advocate for ending fossil fuel extraction. Renewable energy events invited smaller companies with novel technologies. The French utility company EDF was the only oil and gas affiliate invited to speak about raw materials in an event organised by several nuclear

trade associations, which is expected due to EDF's large business portfolio in nuclear. Overall, side events have been venues to extend engagements in a broader range of organisations, with fossil fuel events showing more collaborative patterns.

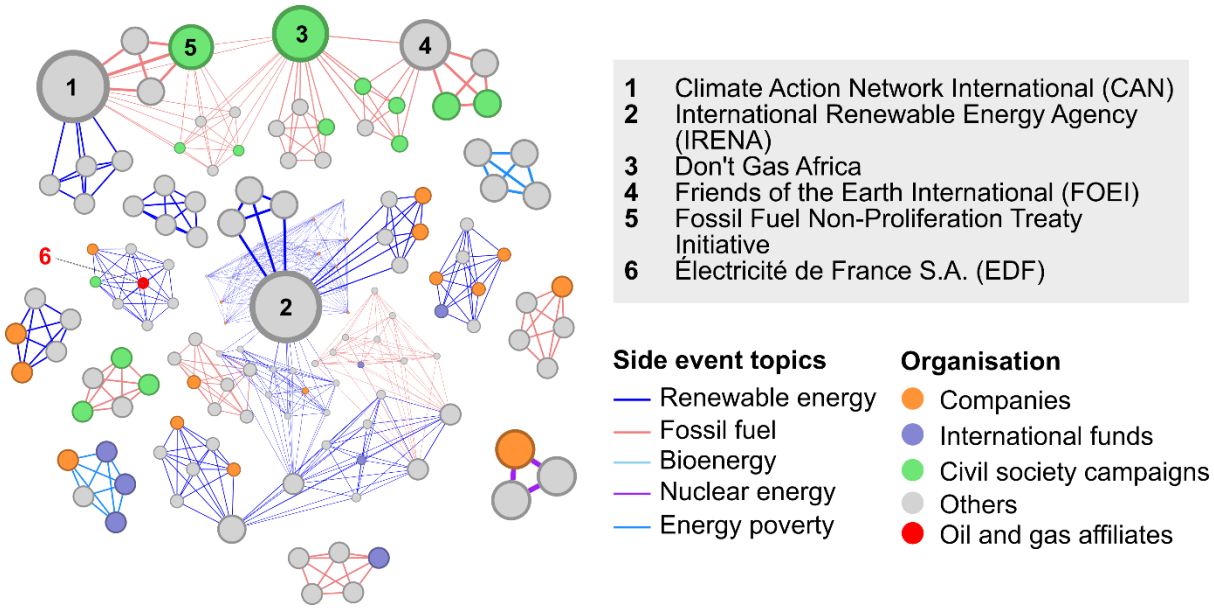

Fig. 6 | Speaker organisation networks for energy side events during COP28. Node sizes represent weighted degrees. Edge colours refer to the side event topics and node colours refer to the type of speaker organisation. The speaker network represents 24 energy side events with a network density of 5.2%, representing completed connections relative to all possible ones.

Discussions

We present an approach to quantitatively trace the procedural dynamics and justice at UNFCCC COPs using diverse datasets emerging from the increasingly complex conferences. We found a consistent prominence of energy topics, which includes an emerging focus on fossil fuel phase-out in the past decade which aligns with recent progress in commitments. The attention on food topics has also increased over the years, while interest in forest management reduced. High-polluting businesses in both energy and food sectors gain access to COPs through governments in developing countries and through business NGOs in developed countries. These NGOs also form well-connected networks among themselves and with developed country Parties. While research and environmental NGOs in developed countries organised most side events, the invited speakers represented a broader range of civil society activists and smaller businesses. This dynamic reflects the additional effort and responsibility required of developed countries, but it is unclear whether representatives from developing countries have equal

access to lead the discourse. Side events surrounding fossil fuel topics have grown substantially in the past decade along with remarkably collaborative efforts from NGOs, which may illustrate civil society's frustration with inadequate fossil fuel phase-out commitments. Organisations affiliated with oil and gas companies have limited engagements in organising and speaking at side events, which are intended for oversight and raising ambition. While they play a passive role in these venues, questions remain regarding the influence they assert through other activities at COPs and whether civil society groups share similar political influence in these other venues.

This work is largely constrained by the data availability and quality. For example, we are only able to identify the organisation affiliations reported to the UNFCCC, which underestimates the complexity of people's affiliations in the real world. This analysis does not trace lobbying mechanisms through informal connections and other events at COPs including pavilion events (no centralised data) and press conferences (ad hoc). The benefit of analysing UNFCCC-managed side events is the opportunity to facilitate and improve procedural justice, compared to more decentralised processes. However, establishing mechanisms to record other activities and engagements could help better quantify the procedural compliance at the conference. Within side events data we obtained, vaguely phrased or incomplete descriptions reported usually at the time of event application months before COPs can influence the result of the topic modelling. As Automatic Speech Recognition technologies develop, publicly available video recordings of events at COP can be used to shed light on the language used by different groups and for sentiment analysis, but caution should be paid to the internal biases of models that can lead to patterns of discrimination[50]. Criticism of the conventional format of side events also urges more participatory dialogues[51], where quantitative social science can systematically synthesise the insights. Recognising that co-hosting side events can be an artefact of the UNFCCC Secretariat's facilitation effort, future work can explore whether organisations without prior connections establish deeper collaborations after COPs.

We argue that quantitative analyses of COP processes would be the first step to understanding and addressing inequities, which fill a knowledge gap in the procedural landscape. For example, the lack of women's participation in UNFCCC constituted bodies and Party delegations was noted in COP18, which led to several mechanisms to track the progress and improve the status quo[52]. The UNFCCC Secretariat's updated participant disclosure requirements since COP28[53] provide valuable data for further research. While side events fall outside of the decision-making mechanism at COP[2], the procedural justice

of non-state actor inclusion in international climate governance is crucial to ensure the transparency and accountability of the process. Although we do not make value judgements of justice, this work provides a framework to operationalise and interpret current progress. With quantitative insights on side event topics and organisations, further research can better understand the impact these activities make towards decision outcomes and climate action progress. New metrics of more equitable engagement can be developed with input from stakeholders. This work also explores only a focused snapshot of non-state actor activities in intergovernmental negotiation spaces. Future work can also explore spaces dedicated to non-state actors such as the Race to Zero or Global Climate Action campaigns.

At the time of writing, preparations are underway for COP29 in Azerbaijan and COP30 in Brazil, which are crucial in the implementation of decisions at COP28. The ambition of Azerbaijan around the fossil fuel discourse and Brazil around food and agriculture will be particularly relevant. To deliver the "tripling renewable energy capacity by 2030"[24] goal, future renewable energy side events could facilitate collaborations beyond siloed connections across the US, EU, and China[54]. The UNFCCC secretariat could make efforts to expand the leadership of side events from organisations based in non-Annex countries. With the growingly diverse participation at COPs in future years, the quantitative research framework introduced in this work can help facilitate procedural justice in the process and highlight existing best practices.

Methods

Data collection

COP28 delegation. The on-site participant list was downloaded from the UNFCCC website (https://unfccc.int/documents/636674) (22nd December 2023 version). COP28 was the first COP to publish the full list of participants as an Excel file with information including nominating entities (delegations), nominated individuals' formal affiliations, their relationships with the nominators (if they choose to declare), and badge types. Previous COPs provided PDF documents with sometimes incomplete affiliations. 69,999 participants were found to have participated on-site out of the 81,027 provisionally registered participants (https://unfccc.int/documents/634503). Participants are categorised through badge types as representatives of Parties to the Convention and Observer States, members of the press and media, and representatives of observer organisations. National delegations, formed by representatives of parties, consist of officials authorised to represent and negotiate on behalf of their governments. Observer organisations include delegates from the United Nations System and its Specialised Agencies, intergovernmental organisations (IGOs), and non-governmental organisations (NGOs)[1].

Organisation constituency and location. The official admitted NGOs details were scraped from the UNFCCC website (https://unfccc.int/process/parties-non-party-stakeholders/non-party-stakeholders/admitted-ngos/list-of-admitted-ngos, accessed 31st January 2024) using the BeutifulSoup Python package. The data include the official names, country of registration, and constituency (type of NGOs). The constituency types include Environmental (ENGO, including Climate Action Network and Climate Justice Now), Research and Independent (RINGO), Youth (YOUNGO), Farmers, Women and Gender (WGC), Business and Industry (BINGO), Local government and Municipal Authorities (LGMA), Indigenous peoples (IPO), and Trade Union (TUNGO). We assume the country and Annex affiliation of organisations based on the location of their headquarters. The official accredited IGOs details were also scraped from the UNFCCC website (https://unfccc.int/process/parties-non-party-stakeholders/non-party-stakeholders/admitted-igos/list-of-admitted-igos, accessed 13th February 2024). United Nations agencies are cross-checked manually.

Interest group identification. The identification of fossil fuel interest groups is based on the companies with the largest market capitalisation[55]. For meat and dairy interest groups, no specific database was available, and we identified companies according to a prior

publication listing the 35 largest meat and dairy companies[44]. Given the inconsistent nature of self-reported company affiliations of COP delegates, we convert the several ways the company names (including different suffixes and capitalisation) may be represented into standardised names. Two authors independently and manually verified the participant entries to ensure no affiliations were incorrectly included. We assume any delegate whose main affiliation is with either industry shares the interest in continuing business, even if the delegate's role is to expand the business portfolio to more sustainable functions. We further identify the country affiliation of NGOs based on the location of their headquarters, but such identification does not infer that the NGOs share the same interests with the governments.

Historical side events. Details of historical side events titles, descriptions, and organisers across 20 years (COP9 in 2003 to COP28 in 2023) were scraped from the archive of UNFCCC Side Events and Exhibits Online Registration System (SEORS) (https://seors.unfccc.int/applications/seors/reports/archive.html) using BeautifulSoup and Selenium Python packages. Because web entries were submitted long before the events took place, the detailed speaker information was often vague or incomplete and thus excluded from the analysis. The data cleaning process includes the following: First, we drop duplicate entries in COP26 and a test entry in COP12. Second, the entries where event titles or descriptions include the term TBC (*i.e.,* to be confirmed), TBA (*i.e.,* to be announced), and other incomplete descriptions, or are shorter than 10 words are labelled incomplete, which would later be excluded in the topic analysis. Third, we identify the most probable language of the title and description text using the langdetect Python package and Google translate the non-English text to English using the deep_translator Python package. The dataset includes 39 incomplete entries and 24 translations from non-English entries (9 Spanish and 16 French), resulting in 4688 documents for further topic analysis. More information on this dataset can be found in Supplementary Section 1.

COP28 side event speaker organisations. Since the speaker data were not readily collected for historical COPs, we use the recently consolidated video recordings of side events to extract speaker organisations in real-time. We scrap the speaker organisation data at COP28 from the video recordings on the official UNFCCC YouTube playlist (https://www.youtube.com/playlist?list=PLBcZ22cUY9RLMkm-apVgzZ8Jsi0Tsywd3). The transcripts and video metadata were accessed on 3rd March 2024 using the pytube and youtube_transcript_api Python packages. Non-English transcripts recognised by the algorithm were translated using YouTube's native translation feature. We attempted using

BERT for Named Entity Recognition (NER) or Generative Pre-Trained Transformer (GPT) 3.5, but both efforts showed unsatisfactory results in recognising the correct names of organisations due to the low quality of automated transcripts[56]. Thus, speaker organisation data were manually recorded from the transcripts and corrected in context from the video recordings. Side events typically follow the order of moderator(s) introduction, some keynote speeches, a panel discussion, and audience questions. The introduction of speakers sometimes occurs at once early on, while at other times it occurs throughout the video, which contributes to the difficulty in capturing such data. Some video titles are misaligned from the titles reported on SEORS and we use human judgement to match the data.

Topic modelling

We analysed the thematic evolution of all COP side events using the BERTopic[57] Python package, a machine learning pre-trained model designed for extracting and representing latent topics from large collections of textual data allowing for modular combinations of individual processes. This model's unsupervised learning capabilities allowed us to systematically identify, categorise, and track the development of themes[58] discussed in COP side events over two decades without the need for predefined categories. The model follows five basic steps including (1) generating dense vector representations of the textual data using transformer-based embeddings, (2) dimensionality reduction, (3) clustering, (4) document vectorisation, and (5) topic representation.

First, we use the state-of-the-art distilRoBERTa (version all-distilroberta-v1 on Hugging Face https://huggingface.co/sentence-transformers/all-distilroberta-v1) sentence transformer to process the document data in lowercase into a 768-dimension vector space. This sentence transformer is distilled or simplified from the base model RoBERTa, which is a robustly optimised version[59] of the Bidirectional Encoder Representations from Transformers (BERT)[60]. The model limits individual text to 128 words which is more than all event descriptions. Second, the model reduces the data to a 5-dimension space using the Uniform Manifold Approximation and Projection (UMAP)[61], a non-linear stochastic technique that prioritises the preservation of local instead of global structures and uses a relative probability space rather than variance. Third, the dimensionally reduced matrix was clustered using the HDBSCAN algorithm[62], a soft clustering approach where instead of assigning each document to a single topic, it calculates the probability of the document belonging to each of the model-identified topics. This is achieved through the analysis of the document's position relative to the topic clusters in the reduced-dimensional space.

This clustering technique allows for the exclusion of less relevant or noisy data through an outlier category (topic -1), thereby ensuring the relevance and distinctiveness of each topic identified. We require at least 15 documents to form a cluster. Fourth, the resulting documents in each cluster were combined and vectorised into a bag-of-words representation, which shows the frequency of words. English stop words and words that occur in less than two documents were removed while considering both unigrams (single word) and bigrams (two-word combinations). Finally, the model uses the class-based Term Frequency-Inverse Document Frequency (c-TF-IDF) algorithm to identify the differences between clustered documents and their corresponding topic representations[57].

Topic modelling identified the 63 relevant topics with 1351 documents (29%) attributed as outliers. The topic model estimates fewer energy events compared to using a keyword search strategy (Supplementary Fig. 3), especially when the event descriptions provide limited details for interpretation. The latter method, however, can be ambiguous interpreting terms with broad meanings beyond their technical applications. To reduce the information lost in outliers, we conduct outlier reduction by using the c-TF-IDF to assign the outlier documents to existing topics with a 10% minimum similarity score threshold. The resulting assignment containing 377 outliers (8%) is used to update the overall topics. This allowed for a more precise examination of the thematic focus within COP side events, enhancing the clarity and relevance of our findings. The topics selected in this analysis are summarised using the most frequent terms:

- Forest management: REDD, forest, deforestation, forests, indigenous
- Food agricultural systems: food, agriculture, systems, security, farmers
- Renewable energy: energy, renewable, renewable energy, clean
- Fossil fuel: fossil, fossil fuel, fuel, coal
- Bioenergy: bioenergy, biofuels, biochar, change mitigation
- Nuclear energy: nuclear, nuclear energy, nuclear power, power
- Energy poverty: energy, poverty, Africa, local

For visual representation and to facilitate an understanding of the inter-topic relationships, we generated a 2D inter-topic distance map using the dimensionality-reduced topic embeddings. This visualisation provided insight into how topics clustered and diverged, offering a macroscopic view of the thematic landscape across the studied period. Moreover, to capture the temporal dynamics of key themes, we plotted the evolution of energy and food topics over time. This involved tracking the prevalence and

variation of these topics across consecutive COP events, enabling us to discern trends, shifts, and emerging focuses within the climate change dialogue.

Bigram (two-word sequences) analysis was conducted on selected side event topics (namely, energy and food) in each COP using the tm R package. Bigrams with the same roots are manually combined and those with general meaning regarding climate change and side events are removed in the analysis. A detailed list of these assumptions is in Supplementary Tables 1 and 2. Note that each side event can result in multiple instances of a bigram, thus the total bigram frequency can be higher than the topic frequency. The resulting matrix covering all bigrams in each year was sorted firstly by the total bigram frequency over years and second by the bigram frequency at COP28, highlighting the phrases important to the topic over time. The final top ten bigrams were visualised using the alluvial plot feature on ggplot2 in R.

Social network analysis

Networks are made up of actors (nodes) and the relational ties (edges) between them[63]. Based on the use of mathematical graph theory[64], the number and structure of links within a network can provide information about the patterns of interactions and key roles of different actors. The undirected networks on interest group co-nomination and side events collaboration were constructed using the Gephi software[65]. With nodes and edges data, the software calculates network statistics and visualises network graphs using the ForceAtlas2 algorithm[46]. Network statistics include actor-level centrality measures describing the actors' relative positions and network-level statistical metrics describing the connectivity of actors[66]. The network statistics used in this work include,

- Degree, which is calculated from the number of edges connected to a node[67]. This metric represents how well-connected a node is. Along the same line, the weighted degree metric is calculated where the connections are weighted (*e.g.,* co-hosting several events together) instead of being treated the same.
- Betweenness centrality, which is calculated from how often a node falls on the short paths between two other nodes[67]. This metric represents the bridge-building[21] or gate-keeping characteristics of nodes as they provide important functions of connecting two other nodes[66].
- Eigenvector centrality, which is calculated from the first eigenvector of the network adjacency matrix[68]. This metric represents the transitive influence within the network, where a node's importance is based on the importance of its neighbours.

- Network density, which is calculated from the number of actual edge connections divided by all possible connections across all nodes, ranging from 0 to 1. This metric measures whether a network is densely or sparsely connected[66].

Bipartite network of interest group nomination. The bipartite networks of the oil and gas industry and meat and dairy industry access to COP28 were visualised using the Sankey feature in the Python Plotly package, identifying the country Annex and constituency of nominators. They were transformed into one-mode projections in Gephi to analyse the cooperation among nominators and interest group delegates, guided by the theory that co-nomination reflects social ties[69]. The nominator networks link organisations if they nominate common delegates. The edges represent the number of shared company nominations, and the edge weight is the number of times the common nomination is repeated. We are unable to discern whether each participant attended the full event or only joined partially through a "shared badge", thus every participant is assumed to carry the same weight in the network. Network statistics of these nominators can be found in Supplementary Tables 3-4.

Network analysis of side events. The organisations of historical side event hosts were extracted from the SEORS database and names were harmonised based on the list of accepted organisations. For event organisers who reported multiple affiliations, the first affiliation was used. Individually hosted events are excluded from this analysis. Edges are derived from every unique combination of two co-hosts. The weight of each edge is the inverse of the number of edges. The number of edges follows the formulation of a Triangular number. For an event with n co-hosts,

$$edge\ number_n = T_{n-1} = \sum_{k=1}^{n-1} k$$

The invited speaker and panellist organisations were harmonised against the accredited list of organisations. Those outside the list were identified as NGOs, companies, international funds, and civil society campaigns through desk research. International funds are defined as those providing grants and financial assistance, such as the Global Environment Facility. Civil society campaigns are defined as those with advocacy goals, such as the Fossil Fuel Non-Proliferation Treaty Initiative. Each organisation is considered as a node and the edges are calculated in the same method as co-hosts. Network statistics can be found in Supplementary Tables 5-8.

Data availability

This work uses publicly available data on participants, side events, and accredited organisations from the UNFCCC website. Their links and sources are acknowledged in the Methods section as they are being introduced. The Gephi graph files and network statistics are made available in the GitHub repository (https://github.com/judyjwxie/unfccc-cop-analysis).

Code availability

The code used for this analysis is made publicly available on a GitHub repository (https://github.com/judyjwxie/unfccc-cop-analysis) under the Apache 2.0 license. It was developed using R version 4.3.1, Python version 3.10.13, and Gephi version 0.10.

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Author contributions

J.X., N.E., and M.E.D. conceptualised this research. J.X. and N.E. curated the data. J.X. led the formal analysis with support from N.E. on the interest group analysis, M.E.D. on social network analysis, and Y.Y. on the topic modelling and text analysis. J.X. developed the visualisation with support from N.E. J.R. and I.S. provided supervision and J.X. provided project administration. All authors contributed to the methodology and the original manuscript.

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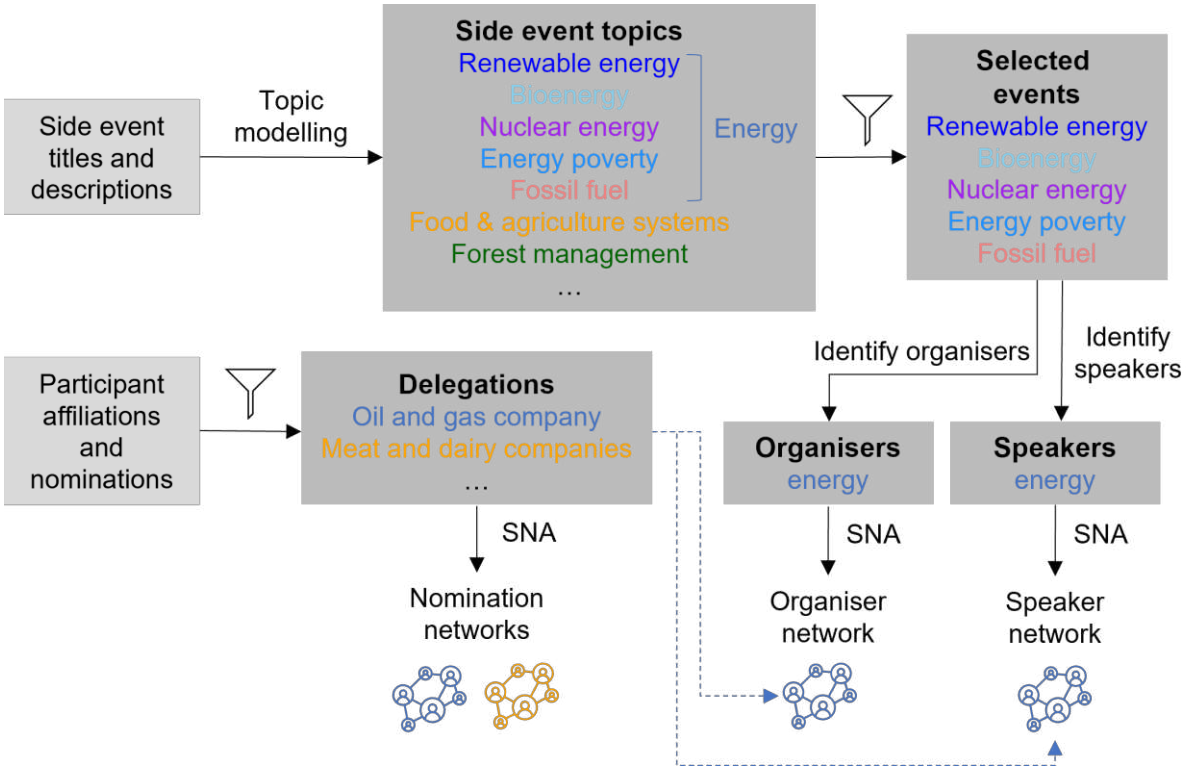
Extended Data Figures



Extended Data Fig. 1 | Methodological framework used in this study. The process takes UNFCCC COP side event titles and descriptions and participant affiliation and nomination information as input data. The filter symbols represent that a subset of the data is selected. SNA means social network analysis.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- COPanalysisv1SI.pdf