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Tracing inclusivity at UNFCCC conferences through side events and interest group dynamics

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Inclusivity and transparency are the foundations of procedural justice in climate governance. However, concerns persist around the influence of business interest groups at United Nations Framework Convention on Climate Change (UNFCCC) Conferences of Parties (COPs). COPs have increased in size and complexity, obscuring agendas and organizational relationships. Here we analyse the discourse and networks of actors at COP side events from 2003 to 2023 using machine learning-based topic modelling and social network analysis. We trace how discussions on energy, food and forests have evolved. Focusing on energy topics, we show that fossil fuel lobbyists gain COP access through developed-country business non-governmental organizations (NGOs) and developing-country governments. Their nominators focus on renewable energy and system approaches but are peripheral in the anti-fossil fuel discourse which grew from a collaborative network of environmental NGOs. Despite data availability challenges, systematically tracing the inclusivity of COP processes can uncover power dynamics at the highest levels of climate governance.

Since its adoption in 1992, the United Nations Framework Convention on Climate Change (UNFCCC) has united the international community to negotiate global climate commitments, particularly at its annual Conference of Parties (COP). The UNFCCC process decides by consensus[1] to ensure that all signatory countries (Parties) assume 'common but differentiated responsibilities'[2] in climate action, regardless of size or economic capacity[3]. The UNFCCC secretariat manages accreditation which grants access to official sessions to eligible non-state participants (Observers) from UN agencies, intergovernmental organizations (IGOs) and non-governmental organizations (NGOs). These accredited organizations may freely nominate members for their delegations[1], providing restricted access to the negotiation site (blue zone). Those with access can influence broader discourse and negotiations through side events, pavilion events or informal meetings. Non-state actors do not directly participate in decision-making for negotiation texts, but they contribute informally[4] by sharing expertise, overseeing the progress of Parties and supporting ambition through a hybrid multilateral governance structure[5–7].

The multilateralism of the UNFCCC process relies on procedural justice[8], ensuring stakeholders equitable 'access to decision-making processes'[9] through justice norms such as participation, transparency, accuracy and correctability[10]. Critics argue that negotiations replicate existing power imbalances and climate injustices[11], advocating for increased involvement of non-state actors in decisions[4]. Side events have been major avenues for non-state actor engagement through knowledge transfer and capacity building, increasing the legitimacy and acceptance of the process[12]. Historically, 60–75% of side events have referenced topics discussed in formal negotiations[13]

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and introduced issues before they became negotiation items[12]. Thus, side events improve representation and procedural justice, and serve as a barometer for non-state actor voices[4].

Business interest groups can rapidly become dominant in transnational climate governance[14], through hedging strategies that engage with least-cost policy design[15]. Despite media concerns about fossil fuel lobbyists at COP28 in Dubai[16], little is known about how they access, engage with discourse or shape negotiations. Participant surveys[12,17] and qualitative analyses[18,19] have been undertaken, but the growing size and complexity of COPs[5] require a more quantitative and systematic analysis of actor networks to reveal emerging influence dynamics.

Machine learning and topic modelling have been used to synthesize text-based climate change information including big literature[20,21], social media sentiment[22] and fossil fuel company communications[23]. Given the importance of international networks underpinning multilateral agreements, social network analysis has explored coalition[24] and connectivity patterns[25] in environmental treaties, collaborations between UN entities on biodiversity[26], IPCC author networks[27], the UNFCCC secretariat's role in non-state actor networks on Twitter[28] and collaborations between NGOs and corporations[29]. Both topic modelling and social network analysis have been combined to investigate the diffusion of youth activism in climate discourse on Twitter[30]. However, our understanding of relationships across non-state actors, particularly those advocating for fossil fuels, and their engagement with the discourse at international climate conferences remains limited. As governance challenges become more diverse and complex, it is increasingly necessary to develop methods that identify the key organizations within these systems, and the broader structures and dynamics across them, to reveal actionable insights[31].

This work aims to quantitatively understand the relationships and discourse of non-state actors and business interest groups at COPs by analysing their discussion topics (what) and networks (who). First, we conduct topic modelling on side events during COP9–COP28 (2003–2023) using natural language processing. Our analysis illustrates the time evolution of side-event topics through the frequency of topic occurrence and the framing patterns in prominent topics (energy, forest management and food). Energy is emphasized because of its importance through side events, emissions and corporate governance. Second, COP28 delegation data are used to map a bipartite network between nominators and fossil fuel lobbyists, identifying the latter's pathways to access COP28. Nominators providing badges for members of the same organizations can reveal their shared interests. Finally, we investigate how organizations (including those associated with fossil fuel lobbyists) engage in COP side events. Networks of energy side-event co-hosts over time and of speakers at COP28 can shed light on the relationships within these organizations. Overall, this work establishes a guiding framework (Extended Data Fig. 1) to trace the increasingly 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 interests in different areas of climate change during COP negotiations and events. 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 (Fig. 1). Overall, 354 events were found across energy, covering various areas including renewable energy, fossil fuels, bioenergy, nuclear energy and energy poverty. The many energy events and breadth of discussions led to subdivisions (Fig. 1), which we considered together. Food and agriculture system topics have grown to >5% of events recently, while forest management topics halved by 2023 from >10% in the 2010s. Energy topics have fluctuated around 5–10% throughout. Analysis of bigrams (two adjacent words) showed how event topics see shifting priorities and framing (Fig. 1).

Energy side events in the 2000s focused on broader bigrams describing clean, renewable and efficient energy. Renewable energy was consistently prominent (5% of all events), which was evident in the tripling by the first global stocktake of the global renewable energy capacity by 2030 goal[32]. The fossil fuel phase-out discourse was limited in the early years[33] despite the scale of its impact (CO_2 from fossil fuels contributed to ~70% of global anthropogenic GHG emissions in 2022[34]). With rising criticism towards the dominant role of high-polluting nations and corporations[35], fossil fuel discussions have increased to nearly half all energy events (3% of all events) since COP17 (2011), covering areas from fossil fuel subsidy reform to phase-out. This growing discourse mirrors recent developments in anti-fossil fuel sentiment[19], where the Glasgow climate pact from COP26 (2021) addressed the topic for the first time[36]. In addition to renewable and nuclear energy, carbon capture and storage (CCS) and hydrogen were listed as essential technologies in the first global stocktake[32], endorsed by oil and gas companies[18], in part due to the transferable knowledge from their core business[37]. The CCS discourse (0.7% of all events) 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 Paris agreement put the issue in its preamble[38]. The just transition discussion included justice principles in fossil fuel phase-out, 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. This growing recognition of the intersectionality at just transition side events was mirrored by similar evolutions on negotiation texts where the labour-oriented concept expanded towards a broader justice framing[39].

Across other prominent topics, scopes have also broadened (Fig. 1 and Supplementary Note 1). Forest management discussions have shifted their focus from readiness and monitoring towards Indigenous peoples, civil society and private sectors. The food-related narrative has evolved from solely focusing on food security to a broader perspective centred around food systems, resiliency and finance. Notably, mention of the meat and dairy industry was absent throughout the discourse despite livestock contributing to 12% of 2015 global GHGs[40], which might be complicated by countries heavily relying on livestock production for food security and economic stability[41].

Paths of interest group access to COP28

Understanding who is represented in COP discussions is essential to investigating inclusivity. This is especially pertinent with carbon-intensive incumbent businesses, whose strategies emphasize engagement with policy regulation[15]. The historical role of carbon-intensive businesses (especially oil and gas) in undermining climate progress has been criticized[18,42,43]. Using new participant data at COP28, we analyse 2,347 delegates (3% of all participants) representing fossil fuel interests as identified by an anti-fossil fuel coalition, the Kick Big Polluters Out (KBPO) coalition[44]. KBPO defines these delegates as those with companies involved with the fossil fuel supply chain and individuals who are assumed to influence policy in the interest of the fossil fuel industry[44]. 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 breadth of fossil fuel interests at COP28 confirms the importance of engagement with the UNFCCC process for the fossil fuel industry[18] and highlights the need for transparency about their presence and influence. Fossil fuel companies have proactively developed energy outlooks and scenarios[42] which introduce their viewpoints and quantitative assumptions in the grey literature.

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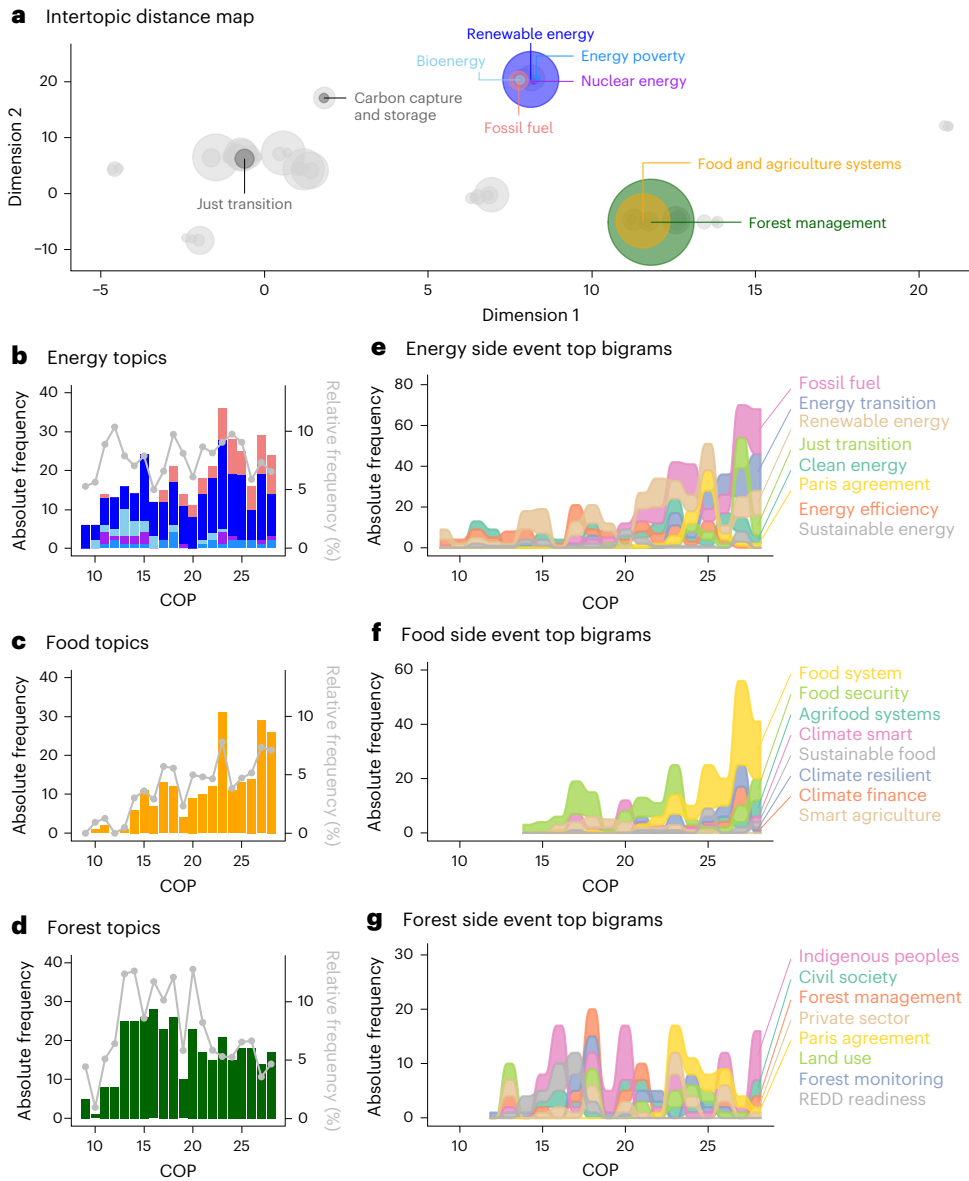

Fig. 1 | Summary of UNFCCC COP side-events topics from 2003 to 2023. The topics are identified by machine learning pretrained topic modelling on side-event titles and descriptions reported to the UNFCCC (Methods). **a**, The intertopic distance map visualizes topics using the two-dimensional projection reduced through uniform manifold approximation and projection (UMAP) (Methods). The sizes of the bubbles represent the numbers of events assigned to the topics. **b**–**d**, The topic occurrence of energy (**b**), food (**c**) and forest (**d**) side events over time in absolute and relative terms. The relative frequency was normalized to the number of side events in each year. The colours in **b**–**d** correspond to the named topics and colours in **a** (for example, dark blue indicates renewable energy). **e**–**g**, The alluvial plots of the top eight most frequent bigrams for energy (**e**), food (**f**) and forest (**g**) side events over time. The terms without line connections are prominent overall but absent in COP28. REDD, Reducing Emissions from Deforestation and forest Degradation.

At COP28, the host country United Arab Emirates (UAE) nominated the highest number (7.6%) of fossil fuel lobbyists, mainly comprising representatives from state-owned businesses. IGOs and UN entities nominated 2.6% of all lobbyists. National fossil fuel companies were mostly nominated through Parties and Party overflows in non-Annex countries (mostly developing countries vulnerable to climate impacts or the economic impact of climate response) and some Annex I (Organization for Economic Co-operation and Development (OECD) and transitioning economies) countries[18], indicating the close relationships between the state-owned companies and governments in these countries. International fossil fuel companies were more connected with varied business NGOs in Annex II countries. The internationally concerted effort in advocacy was exemplified by a controversial leaked letter by the Organization of the Petroleum Exporting Countries (OPEC, an IGO) that urges members to 'proactively reject any text or formula that targets energy, that is, fossil fuels, rather than emissions'[45]. Identifying nominators providing badges for delegates from the same organizations can show the shared interests across these nominators. Connections amongst these nominator organizations through shared nominations can be traced from one-mode projections (Fig. 3) of the nominator–nominee bipartite network (Fig. 2) to infer the influence of organizations (Extended Data Fig. 2). A corresponding network for meat and dairy companies was developed (Extended Data Figs. 3b and 4), although it is much smaller as a result of fewer identified delegates.

The UAE emerged as the most connected node for both degree and eigenvector centrality (Supplementary Table 4), indicating a high number of mutual nominations of fossil fuel lobbyists with other influential organizations. This was followed by centrally located business

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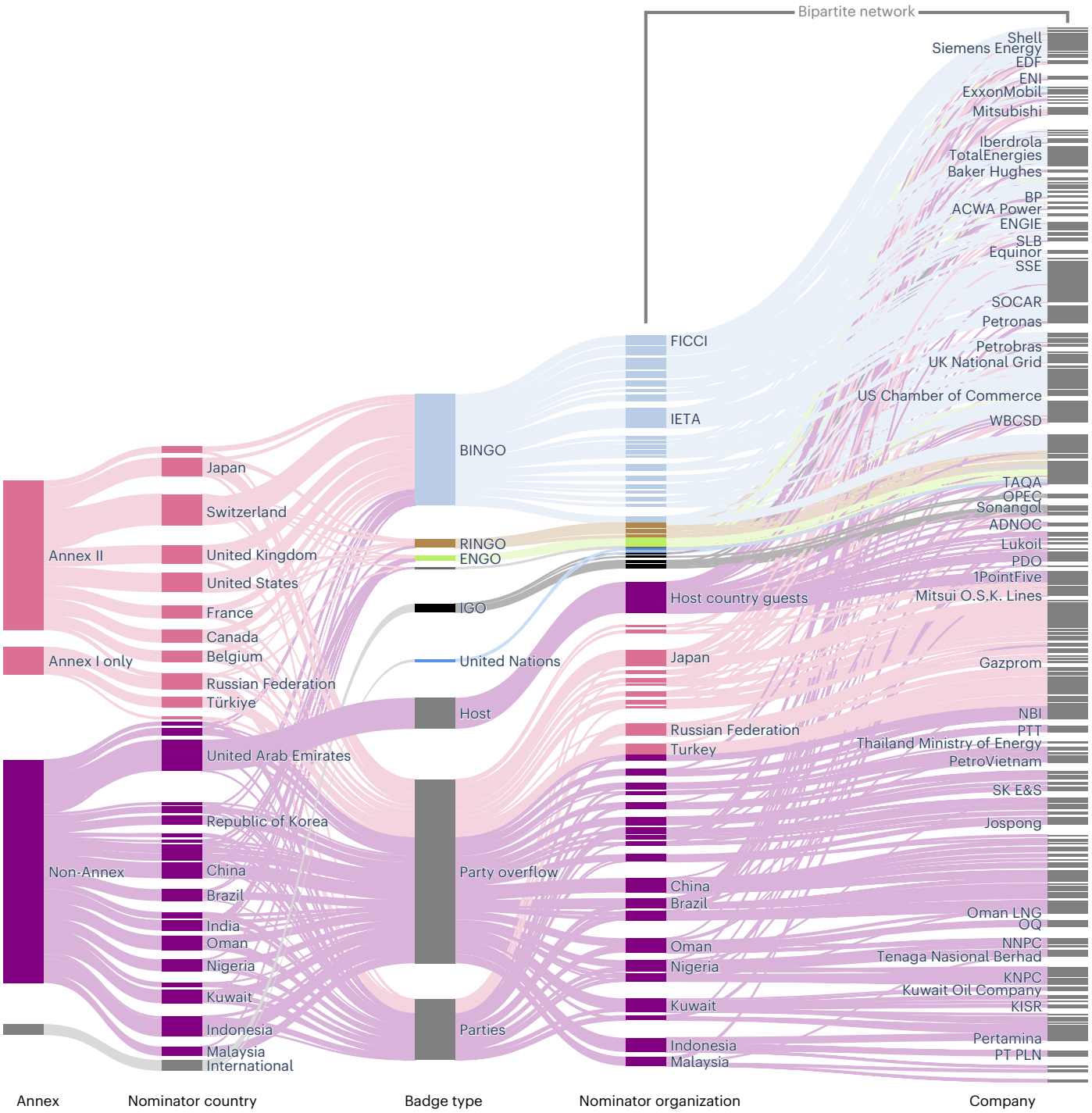

Fig. 2 | Sankey diagram representing fossil fuel companies and lobbyists and their nominators at COP28. Line thickness is proportional to the number of badges issued. The 2,347 delegates were identified through their primary affiliations reported to the UNFCCC participant list as fossil fuel lobbyists or employees of fossil fuel companies[44]. Nominator organizations include observer organizations (NGOs, IGOs and UN entities) and Parties (state representatives). The nominator country affiliations of NGOs are based on their headquarters locations. The companies labelled have more than ten delegates. The nominator organizations labelled provided badges for more than 50 delegates. The grey outlined section marks the bipartite network of nominator organizations and companies, which is then transformed into the one-mode projection (Fig. 3). Badge types: BINGO, business and industry non-governmental organizations; ENGO, environmental non-governmental organizations; and RINGO, research and independent non-governmental organizations. Nominator organizations: FICCI, Federation of Indian Chambers of Commerce and Industry; and IETA, International Emissions Trading Association. Companies: ADNOC, Abu Dhabi National Oil Company; EDF, Électricité de France; KISR, Kuwait Institute for Scientific Research; KNPC, Kuwait National Petroleum Company; NBI, South Africa National Business Initiative; NNPC, Nigerian National Petroleum Corporation; OPEC, Organization of the Petroleum Exporting Countries; PDO, Petroleum Development Oman; PT PLN, PT Perusahaan Listrik Negara; SLB, Schlumberger Limited; SOCAR, State Oil Company of the Republic of Azerbaijan; TAQA, Abu Dhabi National Energy Company; WBCSD, World Business Council for Sustainable Development.

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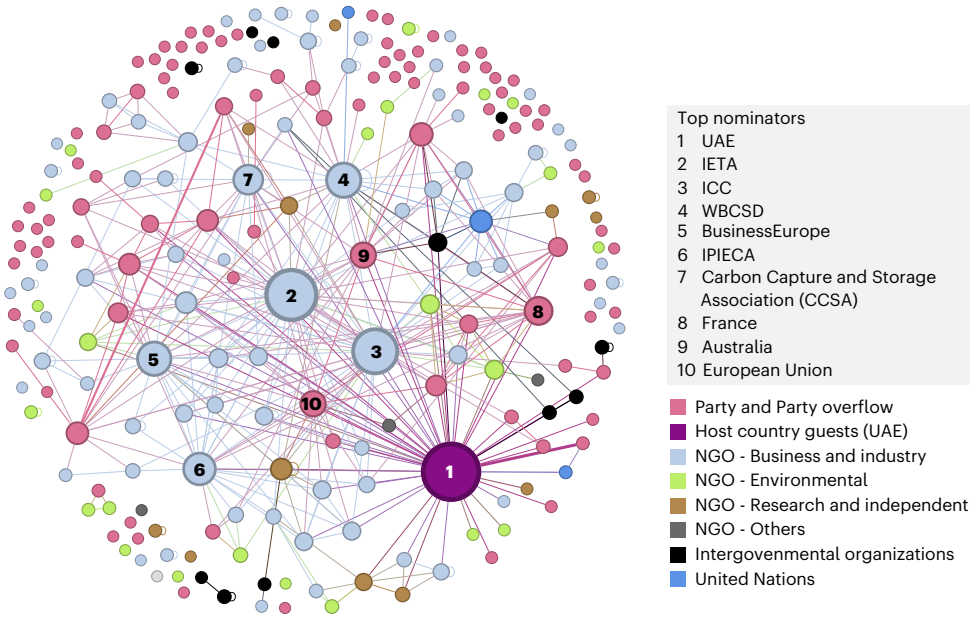

Fig. 3 | One-mode projections for nominators of fossil fuel lobbyists at COP28. The connections across nominator organizations are projected from the bipartite network (Fig. 2). Nodes (circles) represent organizations that nominated fossil fuel lobbyists. Node size represents the degree (number of edges) of a node within each network. Edges (lines) connect organizations that nominated delegates from the same companies. Edge weights (line thicknesses) are the number of shared company nominations between two nominators which indicates some shared interests. Networks for nominators are colour-coded by badge type. Nodes with the highest degree scores are labelled. The network graphs are generated using the ForceAtlas2 algorithm with Gephi[48].

NGOs associated with emission trading and CCS. Major oil and gas company delegates were less than 10% of the International Chamber of Commerce (ICC) and the broadly themed business delegation of the International Emissions Trading Association (IETA) and most of the delegation of the International Petroleum Industry Environmental Conservation Association (IPIECA)[44]. France, Australia and the European Union emerged as the most well-connected Parties behind UAE, while many non-Annex country nominators were more isolated. The prevalence of European trade associations connected with Europe-based international oil companies is aligned with previous research recognizing the proactive attitudes of these companies towards climate change compared to their American counterparts[18,46]. The US Party delegation was notably absent from the nominator network although several US-based business NGOs were present.

Networks of organizations within discourse topics

To understand the organizational relationships and leadership behind the discourse landscape, we investigated side-event organizers by country Annex and constituency, using the energy topic as a case study. Environmental and research NGOs in developed countries hosted more energy-related side events (Fig. 4). Business NGOs were interested in events on energy technologies, while their presence with food events is much smaller (Extended Data Fig. 5). Parties were more involved in hosting energy side events in earlier COPs, but the types of event organizers have diversified. Non-Annex countries are under-represented, hosting 25% of COP28 energy events, despite comprising 78% of all Parties and 83% of the global population. Constituencies including Indigenous peoples, women and youth organize less than 5% while showing improvements in the last two decades. The over-representation of Annex II countries may be due to the higher organizational capacity to coordinate events, so efforts to increase thought leadership from developing-country organizations could improve inclusivity.

Although attributing events to their hosts can showcase the magnitude of the engagement of organizations, questions remain about the relational influence of organizations within their networks. Here, we used social network analysis to investigate both the organizations of high influence (that is, organizing several side events with many others) and those affiliated with business interests through nomination. Entities that organize side events were represented as nodes, with events depicted as edges.

The energy side-event co-host network across COP17–28 highlights broadly sparse connections over time, while events on fossil fuel phase-out shared more dense connections and central positions (Fig. 5). From COP9, energy events were only co-hosted since COP17 when anti-fossil fuel events emerged. Since COP21, environmental NGOs (for example, Center for Biological Diversity and Oil Change International) and their collaborators consistently organized joint events on fossil fuel phase-out, representing a highly dense and central part of the network. Although the discourse on anti-fossil fuel only appeared in the past decade, the organizations were more cooperative and potentially shared a more unified message, putting pressure on ambition[47]. The organizers of renewable energy events were more scattered, with the World Future Council building the most connections. The renewable energy and anti-fossil fuel networks shared some overlaps, but the nuclear network demonstrated distinct organizers. Over time, organizations affiliated with fossil fuel lobbyists represented 16% of the energy event network, focused on mostly renewable energy and were located far from the centre of the network, indicating limited collaborations with others[48]. The organizations in the renewable energy network are interested in whole system approaches involving renewable energy and some have nominated a wide range of fossil fuel lobbyists. Some Parties (New Zealand, Denmark, Finland and Norway) were peripherally linked with the anti-fossil fuel event network through subsidy reform events and one event on phase-out, while our analysis showed that they did not nominate major oil and gas companies during COP28.

As COP side-event applications grew, the secretariat of the UNFCCC may administratively combine events to accommodate more organizations. Thus, the co-hosting relationships could be facilitated by the secretariat compared to speaker invitations from previous connections. We manually extracted the organizations from invited

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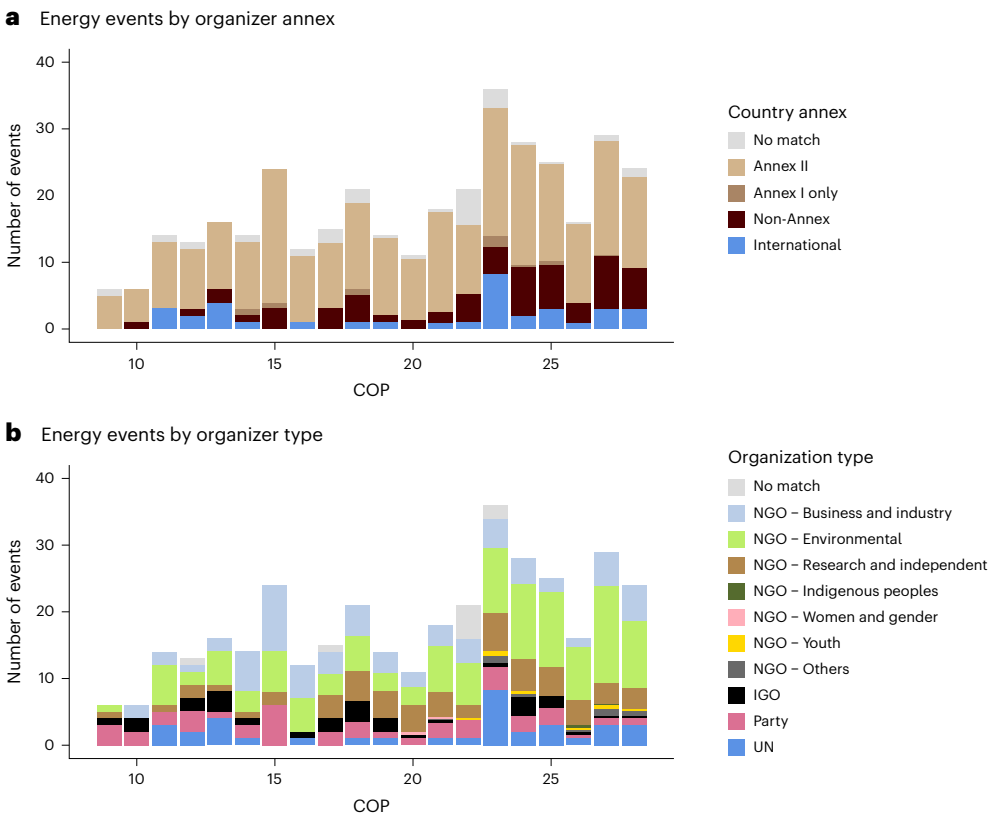

Fig. 4 | Energy side-event organizers attributed to their country affiliations and constituencies. a, Energy side events by country affiliation. **b**, Energy side events by constituency. Sections labelled no match refer to organizations marked in the side-events record but are not on the officially accepted organization list. UN refers to United Nations, related organizations and specialized agencies.

speakers and panellists at COP28 energy events to contextualize the results. Although side-event hosting is restricted to accredited organizations, invites to speakers and panellists are extended to companies, international funds and civil society campaigns (Fig. 6). At COP28, the International Renewable Energy Agency was the most prominent speaker among renewable energy events, followed by the Climate Action Network International 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 new technologies. The French utility company Électricité de France S.A. (EDF, the only company affiliated with fossil fuels) was invited to speak about raw materials in an event organized by nuclear trade associations, which is expected because of the large business portfolio EDF has in nuclear. Overall, side events have been venues to extend engagements in a broader range of organizations, with anti-fossil fuel events showing more collaborative patterns.

Discussion

We present an approach to quantitatively trace the increasingly complex dynamics at UNFCCC COPs using diverse public datasets to understand inclusivity and transparency. This is an effort to systematically identify topical trends in side-event discussions and the networks of non-state actors shaping the discourse. We found a consistent prominence of energy topics and an emerging focus on fossil fuel phase-out in the past decade, aligning with recent progress in commitments. Our analysis of COP participant data (Fig. 2) revealed that fossil fuel lobbyists access COP28 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 organized most side events, the speakers they invited represented a broader range of civil society activists and smaller businesses (identified through event recordings and the websites of organizations; Methods). This dynamic reflects the expectation of developed countries to lead in combating climate change under the UNFCCC and a stronger developing-country focus on adaptation historically. Anti-fossil fuel events have grown substantially in the past decade, along with collaborative efforts from influential environmental NGOs, which may illustrate the frustration of civil society with inadequate fossil fuel phase-out commitments. Such collaboration could be attributed to highly concentrated relational and economic resources within these environmental NGOs[49] and the role of the UNFCCC secretariat in consolidating efforts. Before the focus on phase-out, anti-fossil fuel events historically discussed subsidy reform, aligning with frequent collaborations between NGOs and the banking industry[29].

Side events, intended for oversight and raising ambitions, see limited involvement from organizations affiliated with fossil fuel lobbyists. This mirrors trends from early COPs where industries reluctant to change were not engaged in discussions[50]. We found that most business NGOs do not directly address fossil fuels, focusing more on renewable energy and the broader energy system (Fig. 5). Many were identified through their corporate advocacy for CCS, which has been criticized as misaligned with science-based policies[51]. The misalignment of interests[52] between the broader discourse at side events and fossil fuel interests reflect concerns for the latter's historical involvement in the climate crisis[18,42,43]. While they play a passive role in these venues, fossil fuel companies, especially through their technical

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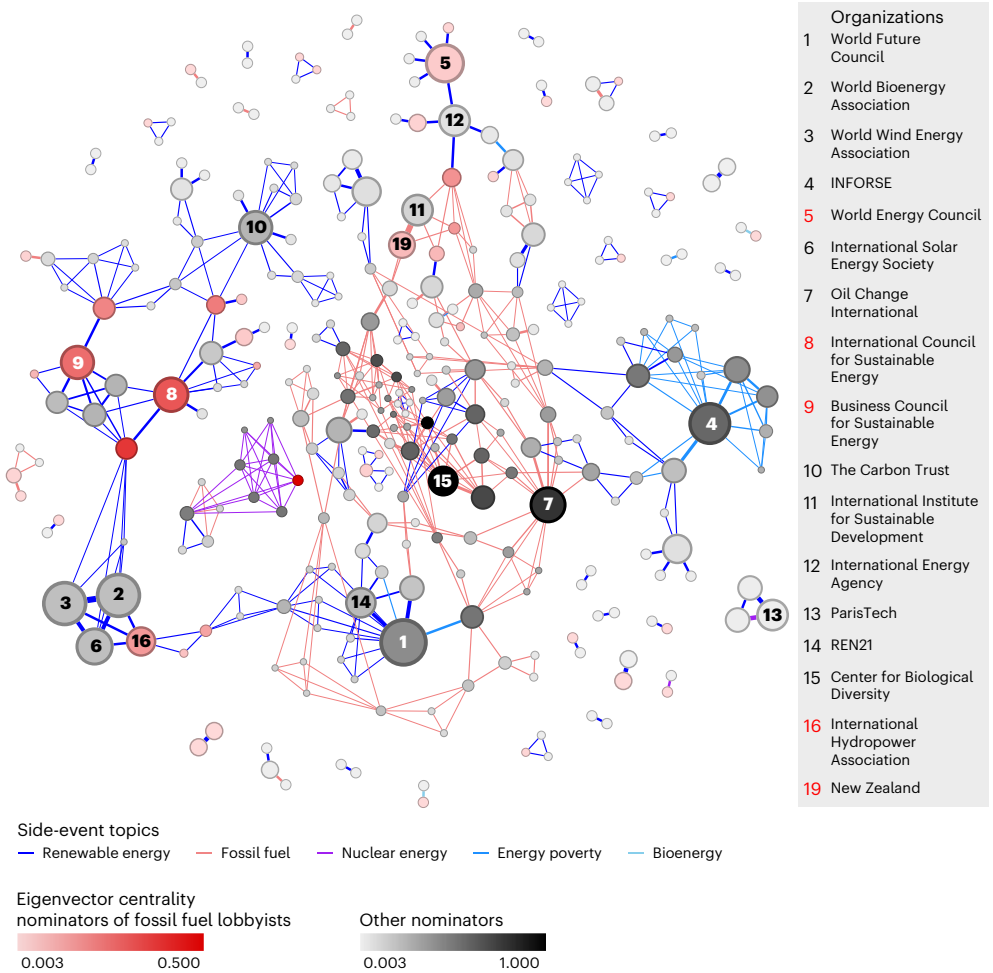

Fig. 5 | Co-host organization networks for energy side events during COP17–28. Node (circle) sizes represent the weighted numbers of events co-hosted, with a larger size indicating a higher number. The numbers are weighted smaller for events with more co-hosts. The co-host network has a network density of 1.1%, representing the numbers of completed connections relative to all possible ones. Edge colour represents the topic of side events. The shades of red nodes indicate the eigenvector centrality values for nominators of fossil fuel lobbyists and the shades of grey nodes indicate the values for other nominators. The network graphs are generated using the ForceAtlas2 algorithm with Gephi[48]. INFORSE, International Network for Sustainable Energy.

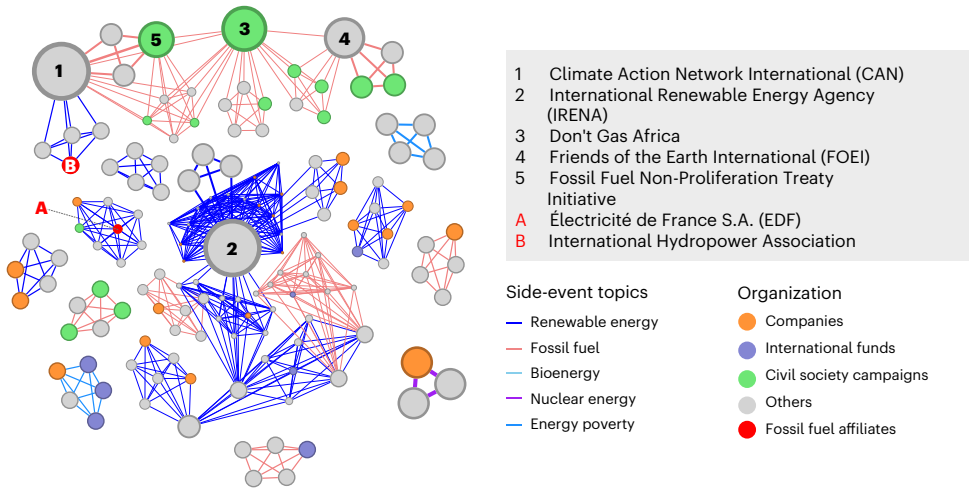

Fig. 6 | Speaker organization networks for energy side events during COP28. Node (circle) sizes represent the weighted numbers of shared events, with a larger size indicating an entity that spoke at more events. Edge colours refer to the side-event topics and node colours refer to the type of speaker organization. The speaker network represents 24 energy side events with a network density of 5.2%, representing completed connections relative to all possible ones. The alphabetical labels represent organizations affiliated with fossil fuel lobbyists and the numerical labels represent other organizations. The network graphs are generated using the ForceAtlas2 algorithm with Gephi[48].

expertise and resources for low carbon technologies[37] and influence on national governments[18], could also engage in rarely disclosed activities at COPs, where civil society groups may not share similar political influence.

This analysis does not trace lobbying through other personal or professional connections and other events at COPs including pavilion events (no centralized data) and press conferences (ad hoc). The observable influences are largely constrained by data availability and quality. For example, we could only identify the organization affiliations reported to the UNFCCC, which underestimates the complexity of real-world relationships. The fossil fuel lobbyist data could be overestimated by companies actively transitioning to renewable energy (for example, Danish energy company Ørsted) and underestimated by incomplete affiliations and hidden ties to fossil fuel interests. However, the trends in access align with those of oil and gas companies, validating the robustness of our results (Extended Data Fig. 3a).

While procedural justice at formal negotiations is supported by the UNFCCC consensus-based decision-making[3], inclusivity at side events is less clear. We do not pass judgement on how fair the current UNFCCC side-event setup is. Rather, we establish a systematic framework (Extended Data Fig. 1) to track and interpret current activities and their impact on COP outcomes. Analysing side events highlights opportunities for the UNFCCC to facilitate and improve inclusivity compared to more decentralized processes. However, this is a focused snapshot of the complex landscape of non-state actors in intergovernmental negotiations. Future work can investigate inclusivity in other non-state actor spaces such as the Race to Zero or Global Climate Action[29] campaigns, while establishing mechanisms to record other engagements to broaden understanding. Criticism of the conventional side-event format also urges more participatory dialogues[53], where quantitative social science can systematically synthesize the insights. Recognizing that co-hosting side events can be an artefact of the facilitation effort of the UNFCCC secretariat, future work can explore whether organizations without previous connections establish deeper collaborations after COPs.

Quantitative analyses of COP processes are the first steps towards understanding and addressing inequities, filling a knowledge gap in procedural justice. For example, the lack of women's participation in UNFCCC bodies and Party delegations was noted in COP18, leading to several mechanisms to track progress and improve representation[54]. The updated participant disclosure requirements of the UNFCCC secretariat since COP28 (ref. 55) provide valuable data for this and future research. While side events fall outside COP decision-making mechanisms[5], there are opportunities to broaden transparency and inclusivity with non-state actor engagement. This could include providing mechanisms to enable under-represented groups to lead discussions and differentiating organizations affiliated with lobbying interests within the accreditation process.

Broadly, this work can expand understanding beyond COP28. The climate ambitions at COP29 in Azerbaijan around the fossil fuel discourse and at COP30 in Brazil around food and agriculture (Extended Data Figs. 3b, 4 and 5) are particularly relevant. Our analysis of event organizers shows the UNFCCC secretariat could further expand the leadership of side events from organizations based in non-Annex countries. With increasingly diverse participation at COPs, the quantitative research framework introduced in this work can support more inclusive processes and uncover existing best practices.

Online content

Any methods, additional references, Nature Portfolio reporting summaries, source data, extended data, supplementary information, acknowledgements, peer review information; details of author contributions and competing interests; and statements of data and code availability are available at https://doi.org/10.1038/s41558-025-02254-9.

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Methods

Data collection

COP28 delegation. The onsite participant list was downloaded from the UNFCCC website (https://unfccc.int/documents/636674) (22 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, making comprehensive analysis before COP28 impossible. The 69,999 participants were found to have participated onsite out of the 81,027 provisionally registered participants (https://unfccc.int/documents/634503). Participants were categorized through badge types as representatives of Parties to the Convention and Observer States, members of the press and media and representatives of observer organizations. National delegations, formed by representatives of Parties, consisted of officials authorized to represent and negotiate on behalf of their governments. Observer organizations included delegates from the UN system and its specialized agencies, IGOs and NGOs[2].

Organization constituency and location. The official admitted details of NGOs were scraped from the UNFCCC website (https://unfccc.int/process/parties-non-party-stakeholders/non-party-stakeholders/admitted-ngos/list-of-admitted-ngos, accessed 31 January 2024) using the BeautifulSoup Python package. The data included the official names, country of registration and self-declared constituency. The constituencies indicated the main areas of focus of organizations and included 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). The two networks within ENGO can coordinate independently in many cases, but we only evaluated the broader ENGO for simplicity. We assumed the country and Annex affiliation of organizations based on the location of their headquarters[49]. We recognize that representatives of these organizations can come from other countries, but individuals' background data are not readily available. Assuming headquarter locations can potentially lead to an underestimation of people from non-Annex countries. Countries in Annex I include industrialized countries and transition economies, within which Annex II countries are those in the OECD responsible for financial and technology support. Countries not in Annex I include developing countries, countries vulnerable to the impacts of climate change and countries vulnerable to the economic impacts of climate response[2]. 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 13 February 2024). United Nations agencies were cross-checked by authors manually. The location affiliations of IGOs and UN entities were identified as international. We categorize accredited organization solely on the basis of these identifications.

Interest group identification. We used a database of fossil fuel companies and lobbyists at COP28 identified by the Kick Big Polluters Out (KBPO) coalition. The database was obtained through the KBPO's COP28 press release[44] on 5 June 2024 and will be publicly available from KBPO for future research purpose. It is based on the UNFCCC participant data with the names of individuals anonymized. Fossil fuel companies were defined as companies involved 'in the exploration, extraction, refining, trading, specialized transportation of fossil fuels or sale of electricity derived from them'[44]. The identification of fossil fuel lobbyists was defined as 'reasonably assumed to have the objective of influencing the formulation or implementation of policy or legislation in the interests of the fossil fuel industry'[44]. To validate the trend of the results, we repeated the main analysis by independently identifying delegates affiliated with major oil and gas companies from the official UNFCCC COP28 delegation database (Extended Data Fig. 3a). We focused on those with the largest market capitalization[56]. We also conducted comparable analysis on the meat and dairy industry (interest groups in the food and agriculture sector) using a list of 35 largest companies identified in a previous publication[43] (Extended Data Fig. 3b). Given the inconsistent nature of self-reported company affiliations of COP delegates, we standardized the several ways that company names could be represented (including different suffixes and capitalization). Two authors independently and manually verified the participant entries to ensure that no affiliations were incorrectly included. We assumed that any delegate whose main affiliation is with a specific industry is interested in continuing business in the industry they are affiliated with, even if the delegate's role was to expand the business portfolio to more sustainable functions. We further identified the country affiliation of NGOs based on the location of their headquarters[49], but such identification did not infer that the NGOs share the same interests with the governments.

Historical side events. Details of historical side-event titles, descriptions and organizers 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 the BeautifulSoup and Selenium Python packages. Because web entries were submitted long before the events took place, detailed speaker information was often vague or incomplete and thus was excluded from the analysis. Vaguely phrased or incomplete descriptions (usually reported months before COPs) can influence the result of the topic modelling and remain a data limitation. The data cleaning process included the following. First, we dropped duplicate entries in COP26 and a test entry in COP12. Second, entries were labelled as incomplete (meaning they were excluded from subsequent topic analysis) where event titles or descriptions included the terms TBC (to be confirmed), TBA (to be announced), other incomplete descriptions or were shorter than ten words. Third, we identified the most probable language of the title and description text using the langdetect Python package and used Google Translate to translate non-English text to English via the deep_translator Python package. This process yielded 39 incomplete entries and 24 translations from non-English entries (9 Spanish and 15 French), resulting in a dataset with 4,688 documents for further topic analysis. More information on this dataset can be found in Supplementary Note 1.

COP28 side-event speaker organizations. Since the speaker data were not readily collected for historical COPs, we use the recently consolidated video recordings of side events to extract speaker organizations in real-time. We scraped the speaker organization data at COP28 from the video recordings on the official UNFCCC COP28 Side Events YouTube playlist (https://youtube.com/playlist?list=PLBcZ22cUY9RLMkm-apVgzZ8JSi0Tsywd3&si=Jt1cb57oL9rO1xQ_). The transcripts and video metadata were accessed on 3 March 2024 using the pytube and youtube_transcript_api Python packages. Non-English transcripts recognized by the algorithm were translated using the YouTube native translation feature. We attempted using BERT for named entity recognition (NER) and generative pretrained transformer (GPT) 3.5, but both efforts showed unsatisfactory results in recognizing the correct names of organizations because of the low quality of automated transcripts[57]. Thus, speaker organization 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, so we used human judgement to match the data.

Topic modelling

We analysed the thematic evolution of all COP side events using the BERTopic[58] Python package. This machine learning pretrained model is designed to extract and represent latent topics from large collections of textual data, allowing for modular combinations of individual steps of analysis. The unsupervised learning capabilities of this model allowed us to systematically identify, categorize and track the development of themes[59] discussed in COP side events over two decades without the need for predefined categories. The model followed five basic steps including: (1) generating dense vector representations of the textual data using transformer-based embeddings, (2) dimensionality reduction, (3) clustering, (4) document vectorization and (5) topic representation.

First, we used 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 lower-case into a 768-dimension vector space. This sentence transformer was distilled or simplified from the base model RoBERTa, which is a robustly optimized version[60] of the bidirectional encoder representations from transformers (BERT)[61]. The model limits individual text to 128 words, which is longer than all event descriptions. Second, the model reduced the data to a five-dimension space using UMAP[62], a nonlinear stochastic technique that prioritizes 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[63], a soft clustering approach where, instead of assigning each document to a single topic, it calculated the probability of the document belonging to each of the model-identified topics. This was achieved through the analysis of the position of the document relative to the topic clusters in the reduced-dimensional space. This clustering technique allowed 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 required at least 15 documents to form a cluster, which was a default assumption balancing the trade-off between providing representative information and model efficiency. Fourth, the resulting documents in each cluster were combined and vectorized into a bag-of-words representation, which showed 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 used the class-based term frequency-inverse document frequency (c-TF-IDF) algorithm to identify the differences between clustered documents and their corresponding topic representations[58].

This topic modelling approach identified 63 relevant topics (Supplementary Table 1). The 3,337 documents (71%) were attributed to one of these topics, with a further 1,351 documents (29%) attributed as outliers. The topic model estimated fewer energy events compared to using a keyword search strategy (Supplementary Fig. 3), especially when the event descriptions provide limited details for interpretation. However, keyword searches can be ambiguous interpreting terms with broad meanings beyond their technical applications. To reduce the information lost in outliers, we conducted 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 contained 377 outliers (8%) and was used to update the overall topics, meaning 92% of all documents were each allocated a topic. This allowed for a more precise examination of the thematic focus within COP side events, improving the clarity and relevance of our findings. The topics selected in this analysis are summarized 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 intertopic relationships, we generated a two-dimensional intertopic distance map using the dimensionality-reduced topic embeddings (Fig. 1a). This visualization provided insight into how topics clustered and diverged, offering a macroscopic view of the thematic landscape across the studied period. To capture the temporal dynamics of key themes, we plotted the evolution of topics over time (Fig. 1e,f). 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.

Analysis of bigrams (two-word sequences) was conducted on selected side-event topics in each COP using the tm R package. We used keyword normalization to map different variations of the same keyword (for example, synonyms and inflectional forms) to a single canonical form. Common stop words (for example, 'with' and 'the') occurred at high frequency and provided limited meaning; thus they were removed in a preprocessing step. Given that all events discuss climate change and side events, we also removed domain-specific bigrams associated with them to avoid losing unique information from more detailed terms. A detailed list of these assumptions is in Supplementary Tables 2 and 3. Note that each side event can result in several 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 first 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 visualized using ggplot2 in R.

Social network analysis

Networks are made up of actors (nodes) and the relational ties (edges) between them[64]. On the basis of the use of mathematical graph theory[65], the number and structure of links within a network can provide information about the patterns of interactions and key roles of different actors. For this research, we constructed two types of networks using the Gephi software[66]—one on the nominations of different interest group organizations to COP28 and another on side-events co-hosts and speakers. With nodes and edges data, the software calculated network statistics and visualized network graphs using the ForceAtlas2 algorithm[48]. Network statistics include actor-level centrality measures describing the relative positions of the actors and network-level statistical metrics describing the connectivity of actors[67]. The network statistics used in this work are:

- Degree, which is calculated from the number of edges connected to a node[68]. This metric represents how well-connected a node is through the number of collaborators. Similarly, the weighted degree metric is calculated where the connections are weighted (for example, 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[68]. This metric represents the bridge-building[26] or gate-keeping characteristics of nodes as they provide important functions of connecting two other nodes[67].

- Eigenvector centrality, which is calculated from the first eigenvector of the network adjacency matrix[69]. This metric represents the influence within the network, where the importance of a node 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[67].

Bipartite network of interest group nomination. The bipartite networks of interest group access to COP28 were visualized using the Sankey feature in the Python Plotly package, identifying the country Annex and constituency of nominators. These networks were divided into two sets of nodes (nominating entities and companies). Using the Gephi software, the nominating entity nodes were transformed into one-mode projections where their shared connections of nominated companies were represented as edges. These shared connections were guided by the assumption that two nominating entities jointly providing badges to delegates of the same company (interest group) would share common interests[70] (Extended Data Fig. 2). For example, two Party delegations nominating employees of a fossil fuel company would share common interests. The edges represent the number of shared company nominations and the edge weight is the number of times the common nomination is repeated. The available data did not state whether each participant attended the full event or only joined partially through a 'shared badge'. Many intangible factors affect how much influence people have (for example, lobbying agenda and closeness with their nominators) and these factors cannot be quantified with the data available. Thus, every participant was assumed to carry the same weight in the network. Network statistics of these nominators can be found in Supplementary Table 4.

Network analysis of side events. The organizations of historical side-event hosts were extracted from the SEORS database and names were harmonized on the basis of the list of accepted organizations. The first affiliation was used for event organizers who reported several affiliations (33 entries or 2% of all organizations). These organizers were predominantly UN or IGOs which are not assigned country or constituency affiliations. Individually hosted events were excluded from this network analysis since they do not form networks. Edges were derived from every unique combination of two co-hosts. The weight of each edge was calculated as the inverse of the number of edges[71,72] to take the social exchange theory[73] into consideration. Social exchange theory postulates that the influence or relational resource that each individual actor receives in collaboration is diluted when more actors are involved. Such calculation emphasizes organizations that both host more events and collaborate more with others. Without accounting for the dilution, we could overestimate the influence of organizations hosting fewer events with more collaborators. We assumed that each collaboration receives the same weight since it is difficult to differentiate otherwise, although some connections might be stronger than others. The number of edges can be calculated from the following formulation. For an event with n co-hosts,

$$\text{number of edges}_n = T_{n-1} = \sum_{k=1}^{n-1} k$$

The invited speaker and panellist organizations were harmonized against the accredited list of organizations. Those outside the list were assigned a category out of NGOs, companies, international funds and civil society campaigns on the basis of self-descriptions from their websites. International funds were defined as those providing grants and financial assistance, such as the Global Environment Facility. Civil society campaigns were defined as those with advocacy goals, such as the Fossil Fuel Non-Proliferation Treaty Initiative. Each speaker organization was considered as a node. The edges represented the same side events at which two organizations have jointly spoken. Network statistics can be found in Supplementary Tables 5–8.

Data availability

This work uses publicly available data on participants (https://unfccc.int/documents/634503), side events (https://seors.unfccc.int/applications/seors/reports/archive.html) and accredited organizations (https://unfccc.int/process-and-meetings/what-are-parties-non-party-stakeholders) from the UNFCCC website. Their links and sources are acknowledged in Methods where they are introduced. The fossil fuel lobbyist data can be accessed upon request to the KBPO coalition. The Gephi graph files, network statistics and all source codes used to generate the visualizations are made available via GitHub at https://github.com/judyjwxie/unfccc-cop-analysis (ref. 74).

Code availability

The code used for this analysis is made publicly available via GitHub at https://github.com/judyjwxie/unfccc-cop-analysis (ref. 74) under the Apache v.2.0 license. It was developed using R v.4.3.1, Python v.3.10.13 and Gephi v.0.10.

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Author contributions

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

Competing interests

The authors declare no competing interests.

Additional information

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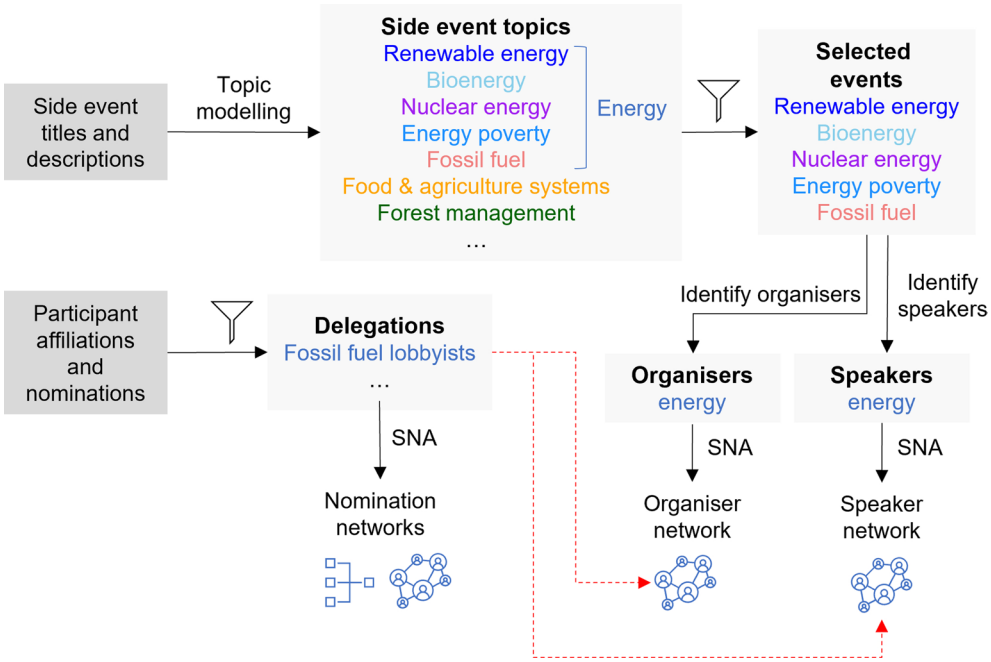

Extended Data Fig. 1 | Methodological framework used in this study. The process takes UNFCCC COP side event titles and descriptions and participant affiliation and nomination information as input data. The filter symbols represent that a subset of the data is selected. SNA means social network analysis.

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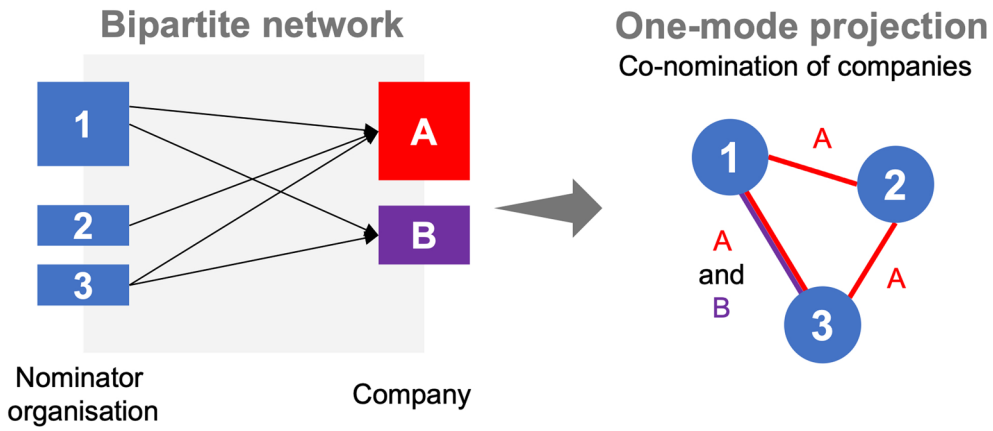

Extended Data Fig. 2 | Example of a bipartite network transformed into a one-mode projection. The bipartite network connects nominator organizations and companies. The nominating entity nodes are then transformed into one-mode projections where their shared connections of nominated companies were represented as edges. When two nominators (*e.g.*, nominators 1 and 3) share more nominations, the strength of their connection, represented by the edge weight, is stronger.

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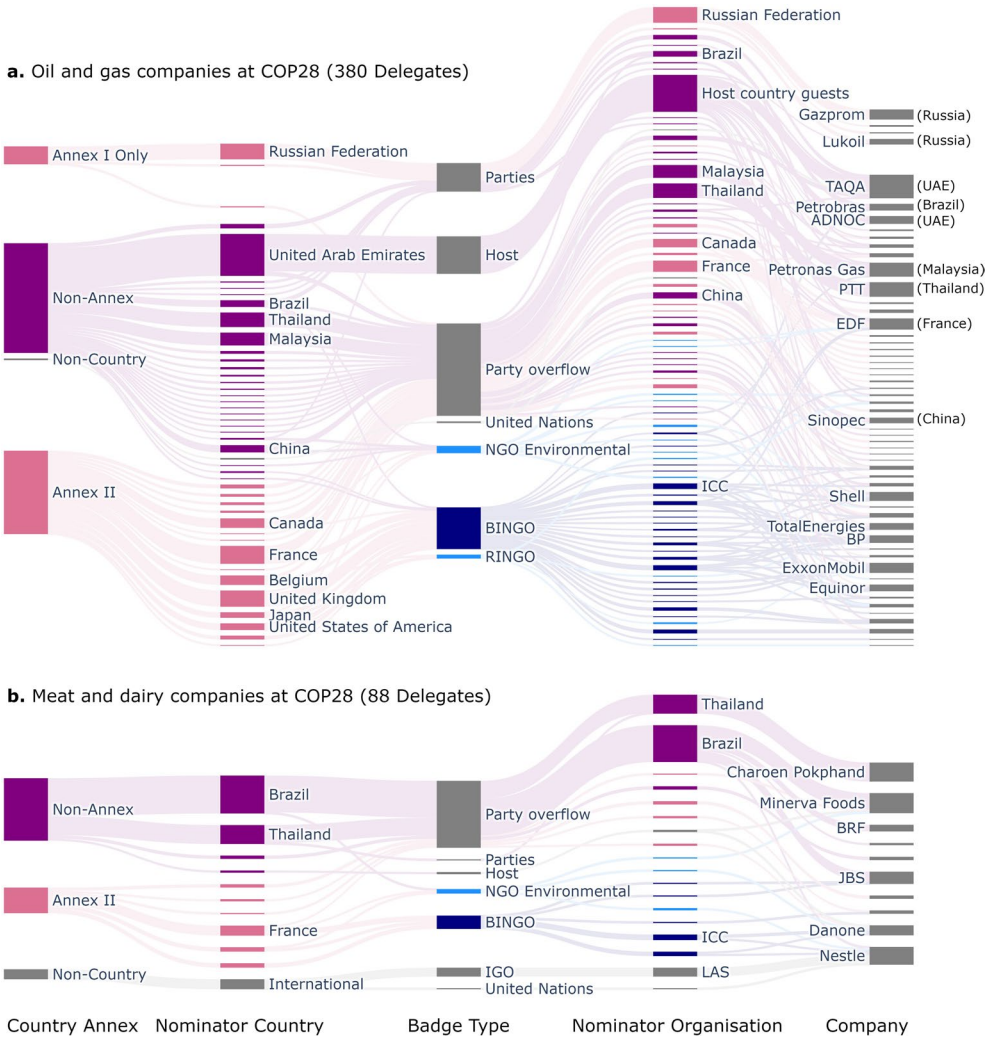
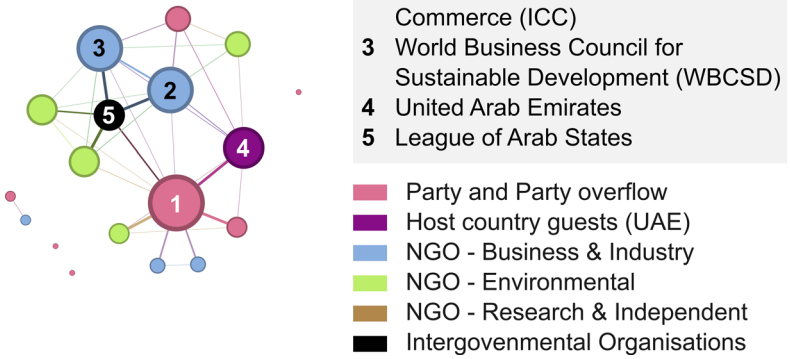


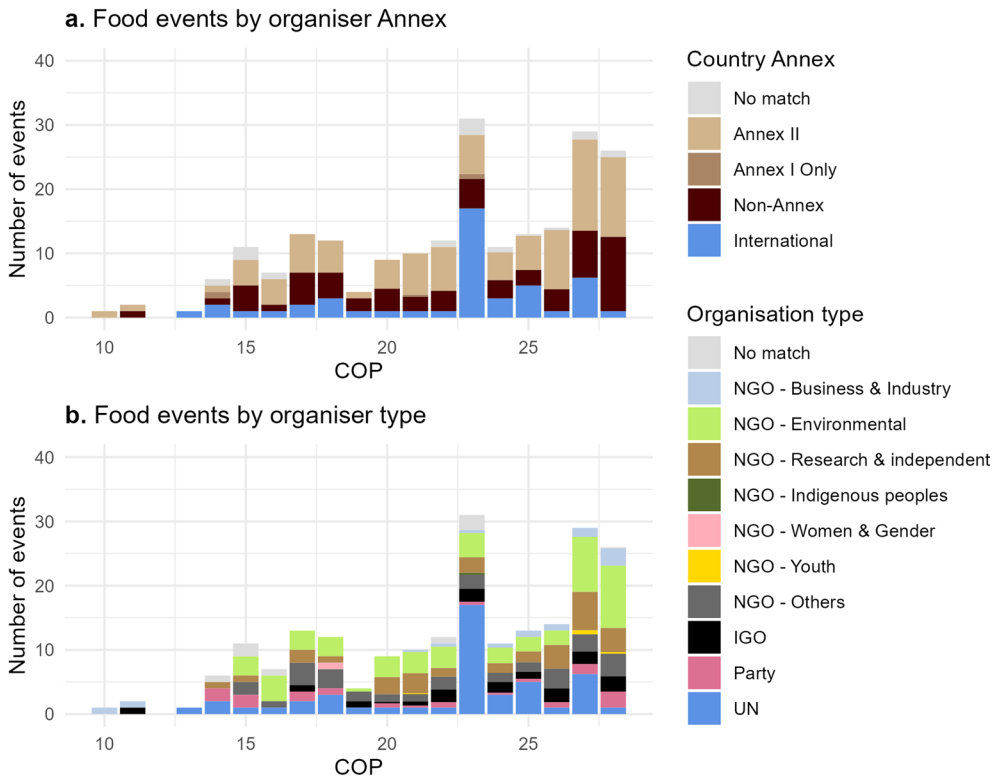
Extended Data Fig. 3 | Sankey diagrams representing the nominators and interest group delegates at COP28. a, **b**, The interest groups include the oil and gas industry (**a**) and the meat and dairy industry (**b**). The companies are selected based on top market capitalizations in each industry. The 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 organization. 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.

https://doi.org/10.1038/s41558-025-02254-9



Extended Data Fig. 4 | One-mode projections for the nominators of meat and dairy companies at COP28. The connections across NGOs and Parties are projected from the bipartite network (Extended Data Fig. 3b). Nodes (circles) represent organizations that nominated meat and dairy companies. Node size represents the degree (number of edges) of a node within each network. Edges (lines) connect organizations which nominated delegates from the same companies. Edge weights (line thicknesses) are the number of shared company nominations between two nominators which indicates some shared interests. Networks for nominators are colour-coded by badge type. Nodes with the highest degree scores are labelled. The network graphs are generated using the ForceAtlas2 algorithm with Gephi[48].

https://doi.org/10.1038/s41558-025-02254-9



Extended Data Fig. 5 | Food side event organizers attributed to their country affiliations and constituencies. a, Food side events by country affiliation. **b**, Food side events by constituency. NGO, non-governmental organization. IGO, inter-governmental organizations. UN, United Nations, related organizations, and specialized agencies. Sections labelled no match refer to organizations marked in the side events record but are not on the officially accepted organization list.