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Favourability towards natural gas relates to funding source of university energy centres

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Methane is 28 to 86 times more potent as a driver of global warming than CO_2. Global methane concentrations have increased at an accelerating rate since 2004, yet the role of fossil fuels and revitalized natural gas extraction and distribution in accelerating methane concentrations is poorly recognized. Here we examine the policy positioning of university-based energy centres towards natural gas, given their growing influence on climate discourse. We conducted sentiment analysis using a lexicon- and rule-based sentiment scoring tool on 1,168,194 sentences in 1,706 reports from 26 universities, some of which receive their primary funding from the natural gas industry. We found that fossil-funded centres are more favourable in their reports towards natural gas than towards renewable energy, and tweets are more favourable when they mention funders by name. Centres less dependent on fossil funding show a reversed pattern with more neutral sentiment towards gas, and favour solar and hydro power.

A touchstone in the climate change policy debate is the appropriate role of natural gas, roughly 75–90% of which is methane (CH_4). Methane causes 86 times more global warming than an equivalent amount of CO_2 over a 20 year period. Across all sources, methane is responsible for 30% of the increase in global temperatures since pre-industrial times[1]. The IPCC recently wrote that "mitigation of methane emissions is very likely to be the most powerful lever in reducing near-term warming"[2]. Global methane concentrations have been increasing at an accelerating rate. Growth rates in methane concentrations fell to −5% in 2004, but have been increasing linearly since, with up to 18.4% growth in 2021 (Fig. 1). Fossil fuels and agriculture have been found to contribute equally to increased global methane concentrations[3]. In the United States, 80% of the methane increase from the early 2000s to 2017 came from fossil-fuel-related methane emissions through fugitive pipeline leaks, venting and so on[3].

Natural gas production costs have dropped precipitously due to technological advances in fracking. For example, US production costs decreased 25–30% per well in the 3 years following 2012 despite substantial increases in the horizontal length of oil and gas wells (see https://www.eia.gov/todayinenergy/detail.php?id=25592 and https://www.eia.gov/todayinenergy/detail.php?id=44236). All major fossil fuel companies produce natural gas. Largely because it generates less local pollution when burned than coal or oil, 'natural gas is likely to be the last fossil fuel to remain standing'[4]. US shale gas extraction has increased from a small role in 2004 (4 bft^3 d^{-1} (billion cubic feet per day)) to a dominant one in 2021 (72 bft^3 d^{-1}).

Academic energy centres are at the forefront of policy discussions on the energy transition, providing congressional testimony and writing in the popular press on carbon taxation, carbon capture and storage, and related topics. The US Senate's Energy and Natural Resources Committee convened specifically to receive testimony on MIT's 2011 energy centre report[5] (see https://www.energy.senate.gov/hearings/2011/7/hearing-1FD19B55-9A55-CC31-8FFF-7EA2AC989E29). In arguing for lifting the US oil export ban in 2015, Senate committee chairman Richard Shelby's opening statement invoked a report by Columbia's Center on Global Energy Policy (CGEP)[6]. Drawing on its findings, Senator Shelby claimed 'lifting the ban is likely to reduce the price of gasoline for American consumers by increasing the supply of crude oil available to the world market'. Likewise, US House Resolution No. 702 cited the same Columbia report in highlighting potential economic and security benefits[7] and the report's co-author testified the ban should be lifted. Congress lifted the ban and the United States became a net oil exporter in 2019.

The largest financial contributors to these prominent centres are frequently corporations, including the fossil fuel industry. Resources

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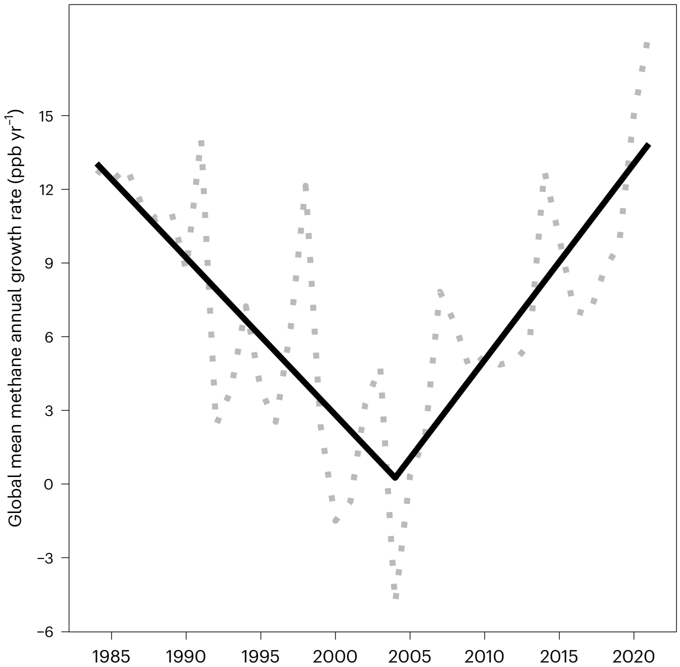

Fig. 1 | Global mean methane concentration growth rates. Atmospheric methane from globally averaged marine surface data. Source: NOAA (https://gml.noaa.gov/ccgg/trendsch4/). Black line shows our ordinary least squares fit of growth = $a_0 + a(\text{year}) + b(\text{year} - 2004) \times (1(\text{year} > 2004)) + \varepsilon$, where a_0 is a constant, a is the coefficient on year, b is the coefficient on (year − 2004) and ε is the error term. The slopes for 1984–2004 and 2004–2021 are −0.64 and 1.44, respectively.

from the fossil fuel industry may facilitate vital independent academic research amidst a long-term decline in government support for universities. Federal funding accounted for nearly 70% of total academic research and development (R&D) expenditures in the early 1970s, while government funds make up just over half (52.9%) of R&D spending today[8]. While there is evidence of corporate policy influence in other settings, to our knowledge there has been no quantitative analysis of industry funding and academic energy research.

Previous work has studied relationships between corporate funding and statements on US federal regulatory rules written by nonprofit organizations. Using text analysis, Bertrand et al.[9] show that nonprofit grantees of corporations are not only more likely to comment on the same rule as their benefactor firm, but their comments are also more similar in content. Earlier research considered links specifically between universities and corporate funding, especially in the context of medical research. For example, an editorial of the journal 'Science' on industry-university biomedical research collaborations observed: "In general, companies pay for research that benefits them and their shareholders…."[10]. Similarly, in 2001 the journal 'Nature' warned of a growing 'university-industrial complex', describing an unease that "global corporations have too much unaccountable influence on institutions, including universities, that are meant to act in the public interest"[11]. Previous qualitative work on the fossil fuel industry and academic research looked at legal agreements between universities and energy firms[12] and highlighted various examples of the fossil fuel industry's capture of academic research[13].

We collected information on funders of major academic energy centres in the United States, the United Kingdom and Canada, and characterized centres as fossil-funded or non-fossil-funded on the basis of information on their main funders (Table 1). There is marked heterogeneity in both how operations are financed and in the transparency of centre funding sources. Some energy centres, such as the University of Chicago's Energy Policy Institute, have a policy of not accepting corporate donations, while others, such as MIT's Energy Initiative (MIT–EI), appear to be mostly industry-funded. Governance relationships also vary across universities. For example, ConocoPhillips, ExxonMobil and Shell 'help establish research priorities' of Stanford's National Gas Initiative (NGI) as members of its governance board (https://ngi.stanford.edu/industrial-affiliates/corporate-affiliates-program, accessed 20 September 2022). Stanford's Corporate Affiliates Program requires a minimum of $250,000 per year in donations for Sustaining Members, wherein Stanford describes "the tremendous opportunities associated with increased production and use of natural gas" (https://ngi.stanford.edu/industrial-affiliates/corporate-affiliates-program, accessed 20 September 2022). At MIT, Eni, Shell and ExxonMobil have made 'founding donations', which secure seats on its MIT–EI's External Advisory Board. The French oil and gas producer Total notes on its website that the company will have a seat on the MIT–EI governing board and that the board "provides key input on the direction and success of the Initiative's research portfolio" (https://totalenergies.com/media/news/press-releases/le-mit-et-total-annoncent-leur-collaboration-dans-la-recherche-energetique-total-sapprete-rejoindre, accessed 20 November 2021). At Columbia's CGEP, eight reports were written by authors who were concurrently working for natural gas-using/promoting companies, according to the Orbis global database.

Our final centre list includes 26 academic centres (3 fossil-funded and 23 non-fossil-funded) with funding information and reports. We then collected 1,706 reports published between January 2009 and December 2020 from these 26 universities, with a total of 1,168,194 sentences. Sentiment analysis of the text provides an objective and comprehensive metric of favourability. We calculated a sentiment score using the Valence Aware Dictionary for sEntiment Reasoning (Vader), a lexicon- and rule-based sentiment analysis tool commonly used in existing research[14–17] to convert text into negative, neutral, positive and compound polarities.

Using our quantification of academic energy centre text output, we evaluated whether the sentiment of text towards natural gas varies systematically according to whether fossil fuel companies are predominant funders. As certain centres may have differing average sentiments in their reports, which we would not want to attribute to differing views on natural gas, we considered how natural gas is viewed relative to alternative, renewable energy sources. Likewise, we expected differing author constellations to have differing average sentiments in the text they generate, which we would not want to attribute to differing views towards natural gas. We therefore evaluated whether average sentiments towards natural gas differ, controlling for differences in average centre sentiment and average sentiment differences across authors within a given centre. We describe our econometric model in detail in Methods, and here summarize our main empirical results.

Results

We take a 'text as data' approach to energy centre reports. These reports are most often the final research product of the centres. Unlike academic working papers, centre reports are commonly distributed with no intention of independent referee and editorial review by scholarly journals. We thus focus first on the data text from centre reports.

Text examples from centre reports

Anecdotally, centre reports can be interpreted as writing favourably about natural gas as a fuel source. For example, MIT's Energy Initiative wrote:

"The U.S. should pursue policies that encourage the development of a [global liquid natural gas] market, integrate energy issues fully into the conduct of U.S. foreign policy, and promote sharing of know-how for strategic global expansion of unconventional gas production."

Table 1 | Fossil-funded and non-fossil-funded academic centre list

University	Centre	Major funders and partners
Fossil-funded (3)		
Columbia Univ.	Center on Global Energy Policy	**Tellurian**, **Occidental Petroleum**, Air Products, Individuals/Anonymous, Breakthrough Energy, CIFF
MIT	MIT Energy Initiative	**Eni**, **ExxonMobil**, **Shell**, **Chevron**, **Equinor**, Iberdrola
Stanford Univ.	Precourt Institute for Energy (Strategic Energy Alliance)	**ExxonMobil**, **Shell**, **TotalEnergies**, Bank of America
Non-fossil-funded (23)		
UC Berkeley	Energy Inst. at Haas	Foundations, Gov't, Individuals, Utilities
UC Berkeley	Cent. for Law, Energy & the Environment	Individuals, Law firms, Zelle
Boston Univ.	Inst. For Sustainable Energy	Breakthrough Energy, British Consulate, Hewlett, Innovation Net. for Communities
Univ. of British Columbia	Inst. For Resources, Env. & Sust.	Gov't
Univ. of Cambridge	Energy Policy Research Group	UK Research Councils
Univ. of Chicago	Energy Policy Inst.	No-corporate-donors policy
Univ. of Exeter	Energy Policy Group	UK Research Councils
Georgetown Univ.	Georgetown Climate Cent.	Foundations
Univ. of Houston	Env., Energy, & Nat. Res. Cent.	Law Firms
Imperial College London	Cent. for Climate Finance & Investment	Quinbrook Infrastructure
UC Irvine	Advanced Power & Energy Program	UC Research Centers, CaSFCC, PARCON, ILAAS
Johns Hopkins Univ.	Initiative for Sustainable Energy Policy	Nonprofit, Research
UCLA	Inst. of the Env. & Sust.	Toyota, Boeing, Utilities, Other Corp.
New York Univ.	Inst. For Policy Integrity	Foundations, Env. Nonprofits
North Carolina State Univ.	NC State FREEDM Cent.	Meta, Utilities
Pace Univ.	Energy & Climate Cen.	Foundations, Gov't
Univ. of Pennsylvania	Kleinman Cent. For Energy Policy	Individuals/Anonymous
UC San Diego	Laboratory on Intl. Law & Regulation	Foundations, UCSD
Stanford	Woods Institute	Individuals (Ward & Priscilla Woods)
Univ. of Sussex	Cent. on Innovation & Energy Demand	RCUK Energy Programme
Tufts Univ.	Cent. for Intl. Resource Policy	Foundations, UK Research Councils, Gov't
UC Joint Institute	CITRIS & the Banatao Inst.	Gov't, Siemens
UK Joint Institute	UK Energy Research Centre	UK Research Councils

Bold text shows fossil fuel industry funders. See Methods for the selection of energy centres. The UC Joint centre is a collaboration between UC Berkeley, Davis, Merced and Santa Cruz. The UK Joint centre is a collaboration among 20 UK universities.

Recommendations are global in scale and extend to developing economies. In a Stanford report, Mark Thurber wrote that "India should not be so quick to dismiss gas as an important part of its strategy for climate change mitigation (and local air quality improvement)"[18]. See Supplementary Information section 9 for additional examples.

Sentiment analysis of text

Coefficient estimates on natural gas are large, precise and consistent across centres (Table 2). Sentences mentioning natural gas are 0.15 more positive than other sentences in the same report. The magnitude of the sentiment increase for natural gas is roughly one-half of a standard deviation (0.34). In contrast, estimates on coal, oil, most renewables and climate change-related keywords are not consistent across centres. The findings indicate that fossil-funded centres are most consistently favourable towards natural gas in their reports.

We pool the 23 non-fossil-funded centres in the last column of Table 2 and in Supplementary Table 3. Estimates on natural gas show a statistically significant 0.06 sentiment increase when natural gas is mentioned, about a third of the pooled estimate for the predominantly fossil-funded centres. One potential reason for the positive sentiment coefficient is that our less fossil-funded centres may also receive fossil funding, given the incomplete funding information on centre websites (and reports). Our 23 non-fossil-funded centres do not mention hydrocarbon corporate funders on their websites but mention other major non-fossil funders (for example, government, foundation, non-fossil-fuel corporate funding). Still, it is impossible to rule out fossil fuel funding for most centres and we only consider direct fossil-fuel funding in our analysis.

The 23 non-fossil-funded centres have a 0.10 and 0.08 sentiment increase in sentences that mention solar and hydro power, respectively, that is, more positive than sentences mentioning gas. Additionally, the 23 non-fossil-funded centres are also positive towards wind energy. We repeat the analysis with energy centres that have at least 1,000 natural gas mentions in their reports (as these centres are more likely to be influential on natural gas). These main results are robust to this alternate specification that includes the same 3 fossil-funded centres

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Table 2 | Sentiment towards each fuel type in predominantly fossil-funded centres' and less fossil-funded centres' reports

	MIT Energy Initiative	Columbia Centre on Global Energy Policy	Sentiment Stanford Natural Gas Initiative	Pooled predominantly fossil-funded	Pooled less fossil-funded
Natural gas	0.165***	0.151***	0.087***	0.148***	0.058***
	(0.029)	(0.021)	(0.025)	(0.021)	(0.015)
Shale gas	0.090***	0.090***	−0.020	0.086***	0.057***
	(0.021)	(0.015)	(0.080)	(0.013)	(0.011)
Methane	0.027	0.022	0.084*	0.039*	0.016
	(0.024)	(0.046)	(0.046)	(0.023)	(0.021)
Coal	−0.044**	−0.004	−0.008	−0.021	0.002
	(0.019)	(0.019)	(0.032)	(0.013)	(0.013)
Oil	0.0443***	−0.0441**	−0.00479	−0.00499	0.00981
	(0.0103)	(0.0178)	(0.0244)	(0.0144)	(0.0101)
Solar	0.122***	0.0789***	0.112**	0.117***	0.0998***
	(0.0225)	(0.0176)	(0.0492)	(0.0201)	(0.0129)
Wind	−0.0062	0.107***	−0.0189	0.0164	0.0507***
	(0.0179)	(0.0236)	(0.0533)	(0.0143)	(0.00916)
Hydro	0.0598***	0.0236	0.0636	0.0444**	0.0751***
	(0.0225)	(0.033)	(0.0871)	(0.0201)	(0.0125)
Observations	100,507	62,999	8,543	172,049	996,145
R^2	0.043	0.079	0.031	0.057	0.072
Y-mean	0.136	0.129	0.114	0.132	0.130
Y-s.d.	0.320	0.372	0.347	0.341	0.333
Replications	1,000	1,000	1,000	1,000	1,000
Report Fes	Y	Y	Y	Y	Y

Standard errors are shown in parentheses. Report Fes, report fixed effects; Y = yes, report fixed effects included. We cluster standard errors at the report level in the left three columns, and at the centre level in the right two columns. Number of clusters = 63, 103 and 18 in individual centre analysis. Number of clusters = 3 and 7 in the pooled analysis on predominantly (less) fossil-funded centres. Given the bias that may result from having few clusters[27], we draw samples of the same size as the data (n = 172,049, n = 435,994) and perform 1,000 replications. Distinct report and centre identifiers are generated in each bootstrap resample. Bootstrap standard errors are clustered at the distinct report and distinct centre level, no. of clusters = 63,000, 103,000 and 18,000 in individual centre analysis, and 3,000 and 7,000 in the pooled analysis. We drop climate change-related keywords in the regression as they are not frequently mentioned and do not show different patterns in the treated and control centres' reports. Results with a full set of controls are shown in Supplementary Table 4. Significance levels are indicated by *P < 0.10; **P < 0.05; ***P < 0.01.

and 13 of the 23 non-fossil-funded centres (Supplementary Table 6). Our results are also robust to a weighted version, where we equate the number of sentences across energy centres (Supplementary Table 7).

To exclude fossil funding entirely and as a robustness check of our sentiment measure, we use the Intergovernmental Panel on Climate Change (IPCC), the Environmental Defense Fund (EDF) and the American Council on Renewable Energy (ACORE) as an alternative comparison group. These organizations also discuss energy sources but have explicit funding information on their websites. For example, according to EDF's corporate donation policy (https://www.edf.org/about/corporate-giving-policy), it will not accept donations from oil/gas, coal mining, oil and gas extraction sectors. These three research institutes are neutral or negative (IPCC) towards natural gas, indicating that the favourable sentiment towards natural gas is not universal in discussions of energy sources (Fig. 2 and Supplementary Table 33).

We also explore heterogeneity across report authors' non-centre affiliations. We hypothesize that individual authors more closely tied to natural gas companies may be more positive towards natural gas than those without corporate affiliations. We indeed find positive estimates on the interaction term (Table 3), indicating that those authors also affiliated with natural gas-using/promoting companies are especially positive in how they write about natural gas in energy centre reports. Still, the coefficient on (uninteracted) natural gas is relatively undiminished, indicating that pro-natural gas sentiment is not accounted for or confined to the subset of authors with gas-related corporation affiliations/histories. Other external organizations show that estimates on natural gas remain positive and similar to the above, but authors working for any company, for-profit companies and fossil-funded nonprofits are not more positive towards natural gas (Supplementary Tables 35–38). Thus, reports by centre authors who also work (Columbia) or previously worked (MIT) for natural gas-related companies write the most positively about natural gas.

Mentions of corporate funders by name

Here we consider the sentiment of centre reports that mention their funders by name and then turn to the more public/popular mentions on social media (Twitter).

Centre reports

Pooling across the three predominantly fossil-funded centres, sentiment score increases by 0.06 (0.036 standard error) when funders are mentioned (Supplementary Table 5). Point estimates indicate that the most positive sentiment is towards funders NRG Energy, Duke Energy and Tellurian (Supplementary Table 23). See 'Funder mentions' in Methods for additional summary and details.

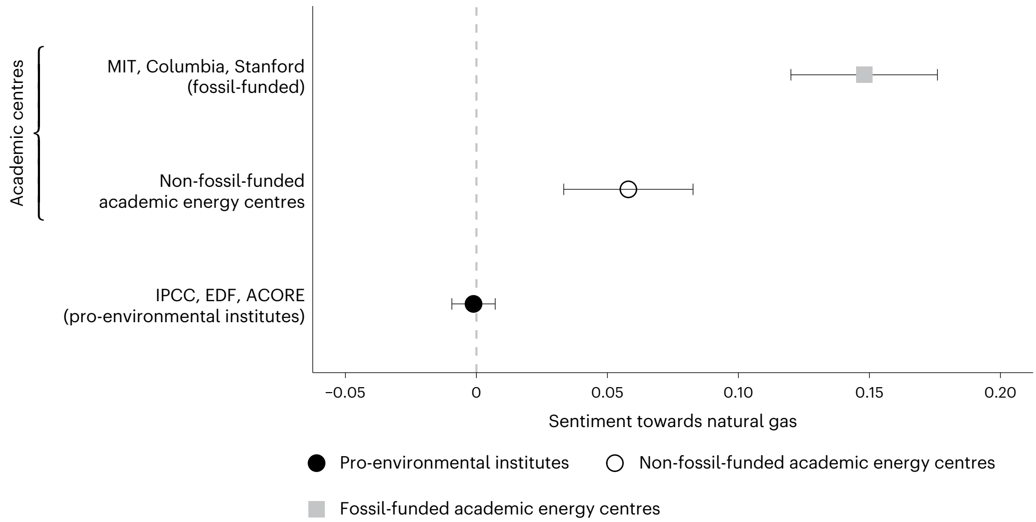

Fig. 2 | Sentiment towards natural gas in predominantly fossil-funded and non-fossil-funded academic centres' and anti-fossil institutes' reports. Point estimates of each institute's sentiment towards natural gas relative to the average sentiment on natural gas in the same report and their 95% confidence intervals. Bootstrap standard errors are clustered at the distinct report level. Fossil-funded academic energy centres: 3 centres, 184 reports, 172,049 sentences; non-fossil-funded academic energy centres: 23 centres, 1,522 reports, 996,145 sentences; pro-environmental institutes: 3 centres, 263 reports, 99,416 sentences.

Centre tweets

Tweets may target a broader and less academic audience than the lengthier reports. While they also mention specific funding companies, we have fewer total 'sentences' to analyse. Tweets by fossil-funded centres frequently mention their own funders by name. The three predominantly fossil-funded centre accounts MIT Energy, Stanford Energy and Columbia CGEP tweet relatively frequently about fossil fuel and electric utilities companies, with 2–4% of their tweets mentioning one of the companies of interest (128, 68 and 439 tweets, respectively; Supplementary Table 45). We find that @StanfordEnergy has the starkest overall pro-funder sentiment. For example, @StanfordEnergy retweeted @exxonmobil's 2018 tweet:

"We are happy to join Stanford University's Strategic Energy Alliance to improve global energy access, security and technology while reducing environmental impact. This adds to the $8B spent by us on lower-emission energy solutions since 2000."

@ColumbiaUEnergy has a significant and positive sentiment towards its funders relative to its other tweets. MIT, Columbia and Stanford centres as a group have a positive sentiment towards their own specific funders in tweets, with a sentiment indistinguishable from 0 (neutral) towards their non-funders. While tweeting about a company is not indicative of endorsement or support, many of these tweets are about funding announcements or events co-hosted with the companies.

Columbia and Stanford's sentiment increases by 0.08 and 0.11 when their Twitter handles mention their funders by name (Table 4). The estimate using MIT's tweets is positive but imprecise. Results on non-funders are inconsistent across these three centres. Stanford and MIT's tweets are negative towards non-funders by 0.2 and 0.004. For Columbia, the estimate on non-funders is positive but smaller than that on funders. Pooling across the three centres, we find a precise and significant 0.08 increase in sentiment when a centre's own funder is mentioned, and conversely, a slight decrease in sentiment when a non-funder is mentioned (not distinguishable from 0).

Discussion

We find that energy centres heavily funded by the fossil industry write reports that are on average positive towards natural gas. Indeed, Stanford, MIT and Columbia together are more positive towards natural gas than renewable energy sources, including solar and hydro power. The magnitude of positive sentiment towards gas is indistinguishable from that of the American Gas Foundation and the American Gas Association (Supplementary Table 31), whose explicit purpose is to promote the gas industry. While academic energy centres less funded by fossil companies are still positive towards natural gas, the point estimate is less than half as large, and solar and hydro power generate a more positive sentiment than gas at the less fossil-dependent centres.

Academic energy centres regularly make policy recommendations and indeed shape major policy decisions. Natural gas is a focal topic. Empirically, emphasis is often on the benefits of gas rather than its costs and externalities. For example, the term 'natural gas' is mentioned seven times more often than 'methane' (a term more often used in relation to global warming) by these three centres. Our regression analysis of sentiment scores indicates that discussions of natural gas are systematically and significantly more positive when the centre is predominantly funded by fossil fuel companies. These centres are even more positive towards natural gas than renewable fuel sources: solar, wind and hydro power.

While these findings may be worrisome to some, they should be viewed as descriptive. We have used publicly available information on centre funding, which typically omit the funding level and the exact dates of support. More precise information on funding amounts and timing would permit stronger empirical tests of the responsiveness of academic report content to funding. Our regression results give the average differences in sentiment related to fuel type (conditional on a fixed effect for each report, which absorbs sentiment differences across entire reports and author sets). While some reports at each fossil-funded centre have positive sentiment about natural gas, our results are consistent with other reports written by the same centre not showing the same positive sentiment. That is, we are not presenting evidence that every report author in a fossil-funded centre writes more positively about natural gas. Instead, the pattern holds on average for the centres that are heavily funded by fossil fuel companies. Similarly, without better data on donation size and timing, we cannot evaluate whether fossil funding to energy centres at Stanford, MIT and Columbia increased in response to their being more positive towards natural gas at baseline than other university centres. Thus, our incomplete funding data do not allow us to reject the possibility of reverse causality.

Given long-standing concerns about the objectivity of corporate-funded research (for example, Nature's editorial[11,19–21]) and recent evidence that suggests corporate grants to nonprofits distort US policymaking[9], there is a strong prima facie case to better

Table 3 | Heterogeneity by report author membership in natural gas-using/promoting companies

	MIT Energy Initiative	Sentiment Columbia Center on Global Energy Policy	Pooled
Natural gas	0.178***	0.115***	0.156***
	(0.041)	(0.013)	(0.022)
Natural gas × Membership	0.059	0.152*	0.107***
	(0.154)	(0.080)	(0.032)
Shale gas	0.083**	0.081**	0.083***
	(0.037)	(0.040)	(0.001)
Methane	0.017	0.030	0.022***
	(0.029)	(0.051)	(0.004)
Coal	−0.0349	−0.00624	−0.0182*
	(0.0238)	(0.0223)	(0.01)
Oil	0.0415***	−0.037*	−0.00451
	(0.0119)	(0.0221)	(0.0275)
Solar	0.117***	0.0929***	0.115***
	(0.0257)	(0.0187)	(0.0098)
Wind	−0.00753	0.111***	0.0223
	(0.0209)	(0.0269)	(0.0438)
Hydro	0.0674**	0.0313	0.0516***
	(0.0267)	(0.0451)	(0.0126)
Observations	76,823	46,892	123,715
R^2	0.038	0.073	0.053
Replications	1,000	1,000	1,000
Y-mean	0.145	0.139	0.143
Y-s.d.	0.325	0.368	0.342
Report Fes	Y	Y	Y

Standard errors are shown in parentheses. Report Fes, report fixed effects; Y = yes, report fixed effects included. Stanford Natural Gas Initiative has no reports written by authors affiliated with natural gas-promoting companies, so we only use MIT and Columbia for this heterogeneity analysis. Summary statistics on author membership are reported in Supplementary Table 34. Bootstrap standard errors are clustered at the distinct report level in the analysis on individual centres, and at the distinct centre level in the pooled analysis, no. of clusters = 71,000, 52,000 and 2,000. Significance levels are indicated by *P < 0.10; **P < 0.05; ***P < 0.01.

Table 4 | Sentiment towards funders and non-funders in predominantly fossil-funded centres' tweets

	Sentiment			
	MIT Energy Initiative	Columbia Center on Global Energy Policy	Stanford Precourt Institute for Energy	Pooled
Funder	0.050	0.080***	0.106**	0.080***
	(0.036)	(0.022)	(0.049)	(0.012)
Non-funder	−0.004	0.078*	−0.182***	−0.019
	(0.051)	(0.042)	(0.053)	(0.063)
Observations	7,556	11,081	6,978	25,615
R^2	0.045	0.038	0.056	0.039
Replications				1000
Y-mean	0.244	0.172	0.163	0.191
Y-s.d.	0.342	0.369	0.372	0.363
Year Fes	Y	Y	Y	Y
Month Fes	Y	Y	Y	Y
DOW Fes	Y	Y	Y	Y
Hour Fes	Y	Y	Y	Y
Centre Fes				Y
Equality test P value	0.391	0.967	0.000	0.156

Standard errors are shown in parentheses. Fes, fixed effects; Y = yes, fixed effects included. Bootstrap standard errors are clustered at the distinct centre level in the pooled analysis, no. of clusters = 3,000. Equality test P value reports whether the estimated coefficients on funder and non-funder are statistically different. A small P value denotes a higher confidence that two coefficients are different. Significance levels are indicated by *P < 0.10; **P < 0.05; ***P < 0.01.

understand industry-funded research in the context of the (costly) transition away from fossil fuels. Bertrand et al.[9] note that policymakers "may not be fully aware of the financial ties between some firms and nonprofits". Universities and their affiliated centres may be viewed by policymakers as even more independent of corporate interests than nonprofit organizations. Meanwhile, the financial ties between academic institutions and corporations are arguably harder to trace: donations to energy centres are inconsistently reported and mostly provided through direct gifts, as opposed to the better-documented charitable foundations investigated in ref. [9]. Therefore, the impartiality of academic energy centre research and attendant recommendations is difficult for most policymakers (or journalists) to gauge. Only 23% of reports published between January 2009 and December 2020 by MIT–EI, Columbia CGEP and Stanford's Natural Gas Initiative included explicit funding acknowledgements.

Lamb et al.[22] argue that the early industry tactic of outright denial of anthropogenic climate change has since evolved into more nuanced 'discourses of climate delay', where the industry now promotes 'non-transformative solutions', redirects responsibility for climate change and asserts that major technological breakthroughs are 'just around the corner'. This forestalls the transition to current renewable energy sources such as solar and wind. From the perspective of Lamb et al.[22], favourability towards natural gas as expressed by academic surrogates, including more recently 'blue hydrogen'[23–26], can be viewed as climate action-delaying tactics. Nevertheless, top research universities continue to receive fossil fuel company donations to fund their energy policy centres. Given familiar concerns about the objectivity of corporate-financed research and the necessity of curbing methane emissions, universities should disclose more detailed information on their funding and governance relationships with fossil fuel companies, as well as any academic content-related conditions specified in individual funding agreements.

Online content

Any methods, additional references, Nature Research 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/s41558-022-01521-3.

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Methods

Methane concentration data collection

We collected global mean methane concentration growth rates from the National Oceanic and Atmospheric Administration (NOAA; https://gml.noaa.gov/webdata/ccgg/trends/ch4/ch4_gr_gl.txt). Before NOAA's global air-sampling network, localized methane concentration samples were available from Antarctic ice. Data in ref. [28] (Table 6) suggest that since 1850, methane concentration growth rates peaked around 1970 and have rebounded starting around 2004.

Federal research funding data collection

We downloaded higher education R&D funding from the National Science Foundation (NSF). We note that while federal funding accounted for nearly 70% of total academic R&D expenditures in the early 1970s, government funds make up just over half (52.9%) of R&D spending today. Meanwhile, expenditures from institutional funds, which include donations from corporations, have increased to 25.7% of academic research budget[8] (Table 1).

Energy centre sample construction

For the fossil-funded centres, we focused on the energy centres of MIT (MIT–EI), Columbia University (CGEP) and Stanford (Precourt Institute for Energy: Natural Gas Initiative). We initially used the Precourt Institute for Energy at Stanford University as our centre of interest, but research publications are not available on its website. Instead, the Precourt Institute for Energy lists 11 affiliated subcentres, and 6 out of 11 subcentres have reports online. Among these 6, we used the Natural Gas Initiative as the treated centre because it publishes substantial fossil-fuel-related reports, is funded by fossil fuel companies and appears to be frequently mentioned by the Precourt Institute for Energy's Twitter account. We chose these energy centres from a list of US-based energy centres compiled by the Wilton E. Scott Institute for Energy Innovation at Carnegie Mellon University (https://www.cmu.edu/energy/events/2019/list-of-u.s.-university-energy-institutes.pdf) as these three stand out as influential centres with substantial fossil-fuel corporate funding.

While we were not able to determine the share of fossil funding on a percent of total budget basis for our fossil-funded centres due to the lack of detailed information on funding sources, we documented substantial evidence of fossil fuel company donations. For example, all of MIT–EI's 'founding members' and about one-third of Columbia CGEP's visionary and leadership annual circle donors are fossil fuel companies. Additionally, we note that CGEP has received more than US$4 million in funding from the hydrocarbon industry since its founding in 2013. Tellurian, Inc. pledged US$2 million to CGEP in March 2019 and 10 fossil firms have donated at least US$200,000 (https://www.energypolicy.columbia.edu/about/partners). Shell alone has donated US$20 million to Stanford's Strategic Energy Alliance.

To define a set of non-fossil-funded academic energy centres, we started with a list of US, UK and Canadian universities with energy centres from US News' 2022 Best Global Universities rankings (https://www.usnews.com/education/best-global-universities/rankings). We supplemented this list with the list of US-based energy centres mentioned above. There are three types of publications on most centres' websites: reports, working papers and journal articles. We excluded the last category in our analysis as journal articles may be more neutral if targeted to and revised in the peer review process. Also, the publication time is less informative than reports and working papers given the longer turnaround time, which makes it problematic to assign author membership. Out of the 46 centres with published reports, we selected ones that listed major funders on their websites, but these funders do not include any fossil fuel companies. For a centre to be classified as non-fossil-funded, there must be major funders listed on the centre website and these must not be any fossil-fuel industry firm or lobby group (for example, American Petroleum Institute (API)). Many of the energy centres have no funding information available, so we contacted these centres via email to inquire about major funders. We excluded centres for which we do not have funding information. We kept centres for which we have funding information, and no listed funder is a fossil-fuel firm. The remaining 23 energy centres are used as our non-fossil-funded group of energy centres.

Further information on energy centre funding

We attempted to gather more precise information on funding amounts and timing. More detailed funding information would permit stronger empirical tests of the responsiveness of academic report content to funding. As this information is not available on centre websites, we reached out to energy centres by email to ask for 'more systematic information on (their) external funders, current and past, including their exact donation amounts and their dates'. The centres we contacted declined to provide us with this information. For example, MIT–EI's executive director replied: "Thank you for your interest in the MIT Energy Initiative, however, we do not have the staff capacity to provide you with the detail you request."

Data collection for sentiment analysis

The texts of energy centre reports were obtained from the centres' websites. We downloaded reports and working papers published between January 2009 and December 2020 (inclusive) from centre websites. We assigned a sentiment score for each sentence on the basis of Vader[29]. Search terms for fuel types and companies are listed in Supplementary Information section 7. Each body of text produced a vector of sentiment scores with negative, neutral, positive and compound polarities. The negative, neutral and positive polarities were normalized to fall between 0 and 1. The compound score could be considered an aggregate measure of all the other sentiments normalized between −1 and 1.

Keyword-based sentiment analysis has been used previously. For example, Reynard and Shirgaokar[30] compared the sentiment of tweets with and without damage- and transportation-related keywords after hurricane Irma. They found that both damage- and transportation-related tweets were more likely to contain negative contents than other tweets in the affected area. Tsai[31] collected COVID-related tweets and analysed people's perception of public health policies. They found that tweets with stay-at-home keywords were positive shortly after the announcement, indicating people's support of the policy, but became negative due to the adverse impacts of the policy. Similar analysis by Box-Steffensmeier et al.[32] shows striking partisan differences in the use of tone in messages about the pandemic.

Frequency of fuel source mention

We began our empirical analysis by quantifying the frequency with which each fuel type is mentioned in centre reports (Supplementary Tables 1 and 2). We also compared fossil fuels and renewables as two broad (undifferentiated) categories, and finally climate change-related keywords. Focusing on 'Fossil' and 'Renewable', MIT had a similar frequency of mentioning these two fuel types, while Columbia and Stanford were three times more likely to mention fossil fuels than renewables in their publications. Additionally, oil was the most mentioned fossil fuel in MIT's and Columbia's reports, taking 4.1% and 10% of all sentences with a keyword. MIT–EI mentioned 'natural gas' in 2,748 report sentences, Columbia CGEP in 1,556 sentences, and Stanford NGI in 929 sentences (2.7%, 2.5% and 10.9% of all report sentences, respectively). Natural gas was more frequently mentioned than oil in Stanford's reports due to the centre's particular focus on natural gas. Methane and shale gas were not frequent terms for any of these three centres. As for specific renewables, only MIT mentioned solar power frequently: about 5,500 times, 5.5% of the total. Hydropower, wind and climate change received little attention from the centres. They accounted for 0.1–0.3%, 0.7–2% and 0.8–4.2% of the total, respectively.

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Sentiment towards fuel types

We used a single-difference design to evaluate centres' sentiment towards different fuel types, formulated as follows:

$$Y_{ijc} = \alpha_0 + \sum_F \beta_f \mathrm{Fuel}_i^f + \gamma_j + \varepsilon_{ijc} \quad (1)$$

where the sample comprises all sentences in reports and working papers published by centres of interest. Y_{ijc} is the sentiment score of sentence i in report j written by energy centre c, and ranges between −1 and 1. Fuel^f_i is a dummy that equals 1 if sentence i includes keywords related to fuel type f and 0 otherwise. We included report fixed effects γ_j, so all static covariates varying across reports are absorbed, including time, author, university, centre and report length. The coefficient of interest β_f captures the difference in the sentiment of sentences with fuel f keywords compared with other sentences without keywords within the same report. If fossil-funded centres are positive towards fossil fuels and negative towards renewables, β_{fossil} is expected to be positive and $\beta_{\mathrm{renewable}}$ is expected to be negative.

Clustering of standard errors

Based on Abadie[27], two reasons for clustering standard errors are sampling design and experimental design. The former reason arises when we collect sampled data from a population using clustered sampling and wish to say something about the broader population. The second concern arises when the causal treatment of interest is clustered. In our analysis, we collected report sentences and tweets from sample centres and would like to generalize our findings to other predominantly or less fossil-funded centres. Also, reports from the same centre had the same author pool and the same funders, so the likelihood of mentioning natural gas or funders at the sentence level was not independent across sentences within a centre. Both sampling design and experimental design required us to cluster standard errors at the centre level in the pooled analysis. For the analysis of individual centres, we did not have a sampling design issue, as we used all report sentences and all tweets from centres of interest. In other words, we analysed the population rather than clustered samples. We clustered standard errors at the report level to address experiment design—the correlation of regressors and errors within reports.

Energy centre tweets

We extended our analysis using energy centres' tweets. Three handles of interest were @mitenergy, @ColumbiaUEnergy and @StanfordEnergy. We returned to our initial treated centre (the Precourt Institute for Energy at Stanford University) for this analysis. The Natural Gas Initiative at Stanford University did not have its own Twitter handle. We used Twitter API to collect all tweets posted by the handles and ended up with 7,556, 11,081 and 6,978 tweets for MIT, Columbia and Stanford, respectively. We collected all tweets posted or retweeted by the three handles of interest. The numbers of tweets were 9,767, 16,487 and 8,081 for MIT, Columbia and Stanford, respectively.

As we were interested in the sentiment of centres rather than retweeted authors, we dropped pure retweets and used only original tweets or tweets with original content in our analysis. We added back pure retweets and found similar results, as shown in Supplementary Table 14. The magnitude of sentiment increase when funders were mentioned was smaller in pure retweets.

We observed the exact tweeting time, tweet text, retweeted handle, number of likes, retweets and comments in each tweet. We added year, month, day of week and hour fixed effects in equation (1) to analyse energy centres' sentiment towards different fuel types in tweets.

Author affiliations

We also tested for heterogeneous effects across author affiliations. We added the variable 'Membership' and its interaction with 'Natural gas' to equation (1). This variable is an indicator that equals 1 if reports were written during their authors' affiliations or after authors worked for natural gas-using/promoting companies. Reports written before affiliations or by never-affiliated authors were coded as Membership equal to 0. Our hypothesis is that authors who worked or are working for corporations may have personal business or financial interests and show different sentiment towards fuel types in the reports they write.

Authors membership data were mainly from Orbis, the largest cross-country firm-level database encompassing firms' financial statements and their production activity[33]. The Orbis data are amalgamated from over 160 different government and commercial information sources and are organized in a standard global format to facilitate company comparisons[33]. We collected information about companies' names, primary products, authors' date of service, position at the company and annual compensation. Other authors' employment data sources included LinkedIn, universities' webpages and companies' webpages. Detailed author affiliations are reported in Supplementary Table 44.

Stanford NGI had no reports written by authors affiliated with natural gas-promoting companies, so we only used MIT and Columbia for this heterogeneity analysis. Summary statistics on author membership are reported in Supplementary Table 34. Columbia authors affiliated with natural gas-using/promoting companies published 0, 8 and 0 reports before, during and after their external service, respectively (Supplementary Table 34). MIT authors published 2, 0 and 3 reports before, during and after external affiliations, respectively. As we used reports produced during or after external affiliations to code Membership, we drew conclusions on Columbia reports produced during their authors' affiliations and MIT reports produced after external affiliations.

Funder mentions

Fuel types aside, we also checked whether reports and tweets are positive when their funders are mentioned. We used a similar single-difference estimation as follows:

$$Y_{ijc} = \alpha_0 + \beta_1 \mathrm{Funder}_{ic} + \beta_2 \mathrm{NonFunder}_{ic} + \gamma_j + \varepsilon_{ijc} \quad (2)$$

where the sample and Y_{ijc} are the same as those in equation (1). Funder_{ic} is a dummy that equals 1 if at least one funder of c is mentioned in sentence i and 0 otherwise. We used a list of potential funding companies to assign $\mathrm{NonFunder}_{ic}$. These companies support other energy centres but not centre i. Coefficient β_1 measures the sentiment change when funders are mentioned, relative to other sentences in the same report. We expect β_1 to be positive if centres tend to write positively about their funders. Coefficient β_2 measures the sentiment change when non-funders are mentioned and is hypothesized to be neutral or negative.

We find there is sentiment change when specific funders and non-funders are mentioned in reports (outside of the report acknowledgements) (Supplementary Table 5). The estimate on Funder in MIT Energy Initiative's reports is 0.09, while estimates for Columbia and Stanford are less precise. Pooling the three centres together, the sentiment score increases by 0.06 (0.036 standard error) when funders are mentioned. When non-funder corporations are mentioned in reports, we cannot distinguish the sentiment difference from 0. Supplementary Table 23 shows sentiment towards individual corporations, regardless of whether they are funders (compared to other sentences in the same centre/report). Pooling across the three predominantly fossil-funded centres, point estimates indicate that the most positive sentiment is towards NRG Energy, Duke Energy and Tellurian. The magnitude of positive sentiment towards these three fossil companies is statistically significant and large: slightly greater than the standard deviation in report sentiment.

Observing an overall sentiment increase when funders are mentioned, we separated funder mentions into those with and without advisory board members at centres. If advisory board members can shape content directly or indirectly, reports should be more positive towards funders with board members than those without board membership. For example, authors may have incentives to speak positively of board members' companies. Results show sentiment increases by 0.13 and 0.08 when funders are mentioned with and without board members, respectively (Supplementary Table 17). The two coefficients are statistically different from each other, with a P value of 0.028. This indicates that the report sentiment is more positive towards funders when funders also have membership on centre boards.

Stock price response to energy centre tweets

We did not see any evidence of a short-term response of funder stock prices to energy centre tweets. We collected daily and intraday stock price data for the publicly traded funding companies of MIT, Columbia and Stanford's energy centres and compared stock prices immediately before and after an energy centre mentioned a funding company in a tweet. We ran this event study analysis with intraday trading data at the 5 min interval level as well as with daily data. We also tested for heterogeneous effects across fossil and non-fossil funders.

Reporting summary

Further information on research design is available in the Nature Research Reporting Summary linked to this article.

Data availability

All datasets generated during and/or analysed during the study are available in the openICPSR repository, DOI:openicpsr-149441[34].

Code availability

The code used to generate all figures and tables is available in the openICPSR repository, DOI:openicpsr-149441[34].

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Author contributions

All authors contributed equally to this work.

Competing interests

The authors declare no competing interests.

Additional information

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Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	Center reports are downloaded from each center's website. Center tweets are collected using Twitter API.
Data analysis	Python: collect tweets. STATA: econometrics analysis. Code and data are available here: Almond, Douglas, Du, Xinming, and Papp, Anna . Data and code for: `` Natural gas policy position of university energy centers relates to their funders''. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2022-09-18. https://doi.org/10.3886/E149441V1

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Our data is available at: Almond, Douglas, Du, Xinming, and Papp, Anna . Data and code for: `` Natural gas policy position of university energy centers relates to their funders''. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2022-09-18. https://doi.org/10.3886/E149441V1

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Policy information about [studies involving human research participants and Sex and Gender in Research.](#)

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Population characteristics	n/a
Recruitment	n/a
Ethics oversight	n/a

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Behavioural & social sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description	Data is quantitative and cross-sectional.
Research sample	For the fossil-funded centers, we focus on the energy centers of MIT (MIT Energy Initiative), Columbia University (Center on Global Energy Policy), and Stanford (Precourt Institute for Energy: Natural Gas Initiative).We choose these energy centers as among a list of US-based energy centers compiled by the Wilton E. Scott Institute for Energy Innovation at Carnegie Mellon University, these three stand out as influential centers with substantial fossil-fuel corporate funding. To define a set of non-fossil funded academic energy centers, we start with a list US, UK, and Canadian universities with energy centers from US News' 2022 Best Global Universities rankings. We supplement this list with the list of US-based energy centers mentioned above. Out of the 46 centers with published reports on their websites, we select ones that list major funders on their websites but these funders do not include any fossil fuel companies. For a center to be classified as non fossil-funded, there must be major funders listed on the center website and these must not be any fossil-fuel industry firm or lobby group. Many of the energy centers have no funding information available; we contact these centers via email to inquire about major funders. We exclude centers for which we do not have funding information. We keep center for which we have funding information and no listed funder is a fossil-fuel firm. The remaining 23 energy centers are used as our non fossil-funded group of energy centers. The text of energy center reports are obtained from centers' websites.
Sampling strategy	We collect all reports and all tweets from the research sample above.
Data collection	We download reports from center websites and collect tweets using Twitter API.
Timing	Reports and tweets published before Jan 1 2021.
Data exclusions	n/a
Non-participation	n/a
Randomization	n/a

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Methods

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☒	☐	ChIP-seq
☒	☐	Flow cytometry
☒	☐	MRI-based neuroimaging