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Assessing ExxonMobil's climate change communications (1977–2014)

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Abstract

This paper assesses whether ExxonMobil Corporation has in the past misled the general public about climate change. We present an empirical document-by-document textual content analysis and comparison of 187 climate change communications from ExxonMobil, including peer-reviewed and non-peer-reviewed publications, internal company documents, and paid, editorial-style advertisements ('advertorials') in *The New York Times*. We examine whether these communications sent consistent messages about the state of climate science and its implications—specifically, we compare their positions on climate change as real, human-caused, serious, and solvable. In all four cases, we find that as documents become more publicly accessible, they increasingly communicate doubt. This discrepancy is most pronounced between advertorials and all other documents. For example, accounting for expressions of reasonable doubt, 83% of peer-reviewed papers and 80% of internal documents acknowledge that climate change is real and human-caused, yet only 12% of advertorials do so, with 81% instead expressing doubt. We conclude that ExxonMobil contributed to advancing climate science—by way of its scientists' academic publications—but promoted doubt about it in advertorials. Given this discrepancy, we conclude that ExxonMobil misled the public. Our content analysis also examines ExxonMobil's discussion of the risks of stranded fossil fuel assets. We find the topic discussed and sometimes quantified in 24 documents of various types, but absent from advertorials. Finally, based on the available documents, we outline ExxonMobil's strategic approach to climate change research and communication, which helps to contextualize our findings.

1. Introduction

In 2016, Attorneys General (AGs) of 17 US states and territories announced that they 'are exploring working together on key climate change-related initiatives, such as ongoing and potential investigations' into whether ExxonMobil Corporation and other fossil fuel companies may have violated, variously, racketeering, consumer protection, or investor protection statutes through their communications regarding anthropogenic global warming (AGW) [1, 2]. (Unless specified otherwise, we refer to ExxonMobil Corporation, Exxon Corporation, and Mobil Oil Corporation as 'ExxonMobil'.) As part of a probe that began in 2015, New York Attorney General Eric Schneiderman has issued multiple subpoenas to ExxonMobil under the

state's Martin Act and alleged that the company's accounting of climate risk 'may be a sham' [3–6]. Massachusetts Attorney General Maura Healey is simultaneously investigating ExxonMobil, stating, 'Fossil fuel companies that deceived investors and consumers about the dangers of climate change should be held accountable' [7, 8]. US Virgin Islands Attorney General Claude Walker has said that he is investigating ExxonMobil for potentially violating the territory's anti-racketeering law [9]. Also in 2016, the US Securities and Exchange Commission (SEC) began a federal investigation into whether ExxonMobil appropriately discloses the business risks of AGW, and how it values its assets and reserves [10]. We offer no view on the legal issues raised by ongoing investigations.

ExxonMobil has responded stating, ‘We unequivocally reject allegations that ExxonMobil suppressed climate change research contained in media reports that are inaccurate distortions of ExxonMobil’s nearly 40 year history of climate research. We understand that climate risks are real. The company has continuously, publicly and openly researched and discussed the risks of climate change, carbon life cycle analysis and emissions reductions’ [11]. In particular, ExxonMobil’s website and statements offer a ‘10 page document listing the over 50 peer-reviewed articles on climate research and related policy analysis from ExxonMobil scientists from 1983 to the present’ [11–15]. ExxonMobil argues that this list, entitled ‘Exxon Mobil Contributed Publications’, ‘undercuts the allegation . . . that ExxonMobil sought to hide our research.’ The company has also published some of its internal company documents, originally made public by journalists at *InsideClimate News (ICN)* [16, 17] (and simultaneously reported by Columbia University’s Graduate School of Journalism and the *Los Angeles Times* [18]), to demonstrate that ‘allegations are based on deliberately cherry-picked statements’ [14]. ‘Read all of these documents and make up your own mind,’ ExxonMobil has challenged [14].

This paper takes up that challenge by analyzing the materials highlighted by the company, and comparing them with other publicly available ExxonMobil communications on AGW. The issue at stake is whether the corporation misled consumers, shareholders and/or the general public by making public statements that cast doubt on climate science and its implications, and which were at odds with available scientific information and with what the company knew. We stress that the question is not whether ExxonMobil ‘suppressed climate change research,’ but rather how they communicated about it [11].

Our analysis covers the publication period of the documents made available by ExxonMobil: 1977–2014. These documents include peer-reviewed and non-peer-reviewed publications (academic papers, conference proceedings, reports, company pamphlets, etc) and internal documents. Our analysis compares these documents with ExxonMobil’s public outreach in the form of paid, editorial-style advertisements—known as ‘advertorials’—published on the Op-Ed page of *The New York Times (NYT)* [19]. We focus on advertorials because they come directly from ExxonMobil and are an unequivocally public form of communication ‘designed to affect public opinion or official opinion’ [20]. Kollman has found that advertorializing is second only to mobilizing group members as the most commonly used outside lobbying technique [20, 21]. We examine whether these communications sent consistent messages about the state of climate science and its implications, or whether there is a discernable discrepancy between the company’s public and private communications.

Our study offers the first empirical assessment and intercomparison of ExxonMobil’s private and public statements on AGW². By bringing to bear the quantitative methodologies of consensus measurement [22, 23] and content analysis [24–28], our results add to (i) earlier analyses of ExxonMobil’s communication practices [19, 20, 29–36], (ii) qualitative accounts of the company’s AGW communications [17, 18, 37–39], and (iii) the application of consensus measurement/content analysis to AGW communications [26–28, 40, 41]. In addition, this study contributes to the broader literature on climate change denial [42–48], corporate issue management [21, 35, 49, 50] and misinformation strategies [51–55], and the social construction of ignorance [56–58].

2. Method

We adapt and combine the methodologies used to quantify the consensus on AGW by Oreskes [23] and Cook *et al* [22] with the content analysis methodologies used to characterize media communications of AGW by Feldman *et al* and Elsasser and Dunlap [27, 28]. Developed to assess peer-reviewed scientific literature, cable news, and conservative newspapers, respectively, these offer generalizable approaches to quantifying the positions of an entity or community on a particular scientific question across multiple document classes.

Our study comprises 187 documents (see table 1): 32 internal documents (from ICN [16], ExxonMobil [59], and Climate Investigations Center [60]); 53 articles labeled ‘Peer-Reviewed Publications’ in ExxonMobil’s ‘Contributed Publications’ list [15]; 48 (unique and retrievable) documents labeled ‘Additional Publications’ in ExxonMobil’s ‘Contributed Publications’ list; 36 Mobil/ExxonMobil advertorials related to climate change in the NYT; and 18 ‘Other’ publicly available ExxonMobil communications—mostly non-peer-reviewed materials—obtained during our research. To our knowledge, these constitute the relevant, publicly available internal documents that have led to recent allegations against ExxonMobil, as well as all peer-reviewed and non-peer-reviewed documents offered by the company in response. They also include all discovered ExxonMobil advertorials in the NYT discussing AGW. Advertorials are sourced from a collection compiled by Polluter-Watch based on a search of the ProQuest archive [61].

² There are, of course, countless additional climate change communications from ExxonMobil that could be included in future work, including archived internal documents, advertorials published in newspapers beyond the NYT, and non-peer-reviewed materials such as speech transcripts, television adverts, patent documents, shareholder reports, and third-party communications (for example, from lobbyists, think-tanks, and politicians funded by ExxonMobil). These documents are potentially important, but are not the focus of the present study.

Table 1. Inventory of documents analyzed. Shown for each document category are the total number of documents, their date range, source(s), and assigned types. Among peer-reviewed and non-peer reviewed documents, eight publications were found to be redundant, with similar or identical wording to seven other (strictly unique) publications. All 15 are included in our analysis. Among non-peer-reviewed documents, there are two citations provided by ExxonMobil that are identical to two others. The identical two are not included in our analysis. Sources: ‘Peer-Reviewed’ and ‘Additional’ publications are cited in the ‘Exxon Mobil Contributed Publications’ list [15]; ‘Supporting Materials’ are internal documents offered by ExxonMobil [59]; ‘Other’ sources refers to documents discovered independently during our research; *ICN* = *InsideClimate News*; *NYT* = *The New York Times*. *NYT* advertorials were collated by Polluter Watch [61]. For details on document types, see section S2, supplementary information, available at stacks.iop.org/ERL/12/084019/mmedia. Miscellaneous Opinions include, for example, commentaries, opinion editorials, and speeches.

Category	No.	Dates	Sources						Document Types							
			Provided by ExxonMobil						Academic journal	Conference/workshop proceeding	Gov. report	Book	Industry white paper	Internal doc.	Ad	Misc. opinion
			'Peer-reviewed'	'Additional'	'Supporting materials'	ICN	NYT	Other								
Internal Documents	32	1977–1995	0	0	22	28	0	1	0	0	0	0	0	32	0	0
Peer-Reviewed	72	1982–2014	50	19	0	0	0	3	53	2	13	4	0	0	0	0
Non-Peer-Reviewed	47	1980–2014	3	29	0	3	0	12	0	24	5	2	2	0	0	13
Advertorials	36	1989–2004	0	0	0	0	36	0	0	0	0	0	0	0	36	0

To characterize each document, we read its abstract, introduction, and conclusion, and either skim or read thoroughly the rest as necessary. In the case of long documents (over ~30 pages) in which executive summaries are provided, we rely on those summaries. The documents are binned into four categories as shown in table 1: *Internal*, *Peer-Reviewed*, *Non-Peer-Reviewed*, and *Advertorial*. This allows us to distinguish communications according to degree of accessibility—a key variable in assessing the consistency of ExxonMobil’s representations of AGW. Each document’s manifest content is then further characterized in four ways: type, topic, position with respect to AGW, and position with respect to risks of stranded assets. Details of document types and topics are discussed in sections S2–3, supplementary information.

2.1. Document position

Research has shown that four key points of understanding about AGW—that it is real, human-caused, serious, and solvable—are important predictors of the public’s perceived issue seriousness, affective issue involvement, support for climate policies, and political activism [62–66]. These four elements have also been found to underpin most narratives of AGW skepticism and denial (namely ‘it’s not happening’, ‘it’s not us’, ‘it’s not serious’, and ‘it’s too hard’) [28, 43, 67, 68]. We therefore use, *a priori*, these recognized elements as axes along which to characterize ExxonMobil’s positions on AGW in its communications; positions on each of these elements form the primary codes in our content analysis (table 2). Our coding scheme is summarized below (see section S1, supplementary information for further details).

One of the authors coded all of the documents, and ambiguities were resolved through discussion between authors. To verify intercoder reliability and intercoder agreement, both authors independently

coded a random subset of 36 documents (approximately 19% of the total number of documents in each category). Intracoder reliability was also calculated (see section S1.7, supplementary information).

2.1.1. ‘Real & human-caused’

Tailoring the approaches of Cook *et al*, Feldman *et al*, and Elsasser and Dunlap, each document is coded by assigning ‘Endorsement Points’ (EP1 to EP4b, defined in table 2) to pertinent text and figures based on whether each acknowledges or doubts the scientific evidence that AGW is real and human-caused (intercoder reliability of Endorsement Points: percentage agreement = 93%; Krippendorff’s (Kripp.) $\alpha = 0.84$) [22, 27, 28]. We recognize that all science involves uncertainties, and therefore that doubt is not, *ipso facto*, an inappropriate response to complex scientific information. Uncertainties are an innate and important part of reasonable scientific discourse. However, it has also been shown that uncertainty may be amplified or exaggerated in ways that are misleading and unreasonable, sustaining doubt about claims that are scientifically established [42, 52, 57, 69]. Therefore, to distinguish reasonable and unreasonable doubt, we apply two first-order filters to our Endorsement Point codings. First, in documents published on or before 1990, we exempt expressions of doubt that AGW is *real* (i.e. we deem such expressions to be reasonable at that time). Second, in documents published on or before 1995, we exempt expressions of doubt that AGW is *human-caused*. 1990 and 1995 are when the Intergovernmental Panel on Climate Change (IPCC) first concluded that AGW is real and human-caused, respectively (these are conservative thresholds insofar as many scientists had arrived at these conclusions prior to the IPCC reports; indeed, IPCC reports are based only on already-completed work) [70, 71]. Finally, based on its individual Endorsement Points, each document is assigned one overall Endorsement

Table 2. Definitions of the Endorsement, Impact, and Solvable Points used to code levels of acknowledgment of AGW as real and human-caused, serious, and solvable, respectively. See section S1, supplementary information, for details on the content analysis and coding scheme.

<i>AGW as Real and Human-Caused</i>		
Endorsement points (EPs)		Description
'Acknowledge' (EP1)	Explicit endorsement with quantification	Explicitly supports position that humans are the primary cause of global warming (with quantification)
	(EP2) Explicit endorsement without quantification	Explicitly supports position that humans are the primary cause of global warming (without quantification) or refers to anthropogenic global warming as a known fact
	(EP3a) Implicit endorsement	Implicitly supports position that humans are the primary cause of global warming. e.g. research assumes greenhouse gas emissions cause warming without explicitly stating humans are the cause
	(EP3b) Implicit endorsement of consensus	Implicitly supports position that humans are the primary cause of global warming by referring to a consensus of the scientific community
'No position' (EP4a)	No position	Does not address the cause of global warming
'Doubt' (EP4b- 1)	Uncertain of reality of AGW	Expresses position that the <i>reality</i> of recent global warming is uncertain/undefined, namely 'it's not happening'
	2) Uncertain of human contribution to AGW	Expresses position that the <i>human contribution</i> to recent global warming is uncertain/undefined, namely 'it's not us'
<i>AGW as Serious</i>		
Impact points (IPs)		Description
'Acknowledge' (IP1)	Acknowledgment	Acknowledges and/or articulates known or predicted negative impacts of global warming e.g. geophysical, economic, socio-political
'No position' (IP2)	No position	Does not address the negative impacts of global warming (beyond generic references to climate change as a 'risk')
'Doubt' (IP3)	Uncertain	Expresses position that the reality of negative impacts of global warming is uncertain/undefined/exaggerated, namely 'it's not bad'
<i>AGW as Solvable</i>		
Solvable points (SPs)		Description
'Doubt' (SP1)	Uncertain	Expresses position that the difficulties of mitigating global warming are potentially insurmountable and/or exceed the benefits, namely 'it's too hard'

Level (EL) (intercoder reliability of Endorsement Levels: 89%; Kripp. $\alpha = 0.85$): 'No Position' (all text and figures are EP4a only); 'Acknowledge' (EP1–3 only); 'Acknowledge and Doubt' (EP1–3 and EP4b); 'Reasonable Doubt' (EP4b only, deemed reasonable as defined above); or 'Doubt' (EP4b only, deemed unreasonable). 'Acknowledge and Doubt' reflects the fact that some communications acknowledge aspects of AGW yet emphasize other areas of doubt or uncertainty.

Our filtering of reasonable doubt (see also section S1.4.2, supplementary information) helps address the challenge of characterizing the positions of documents published during a period of rapidly evolving scientific opinion. Otherwise, however, our coding scheme is agnostic to each document's publication year.

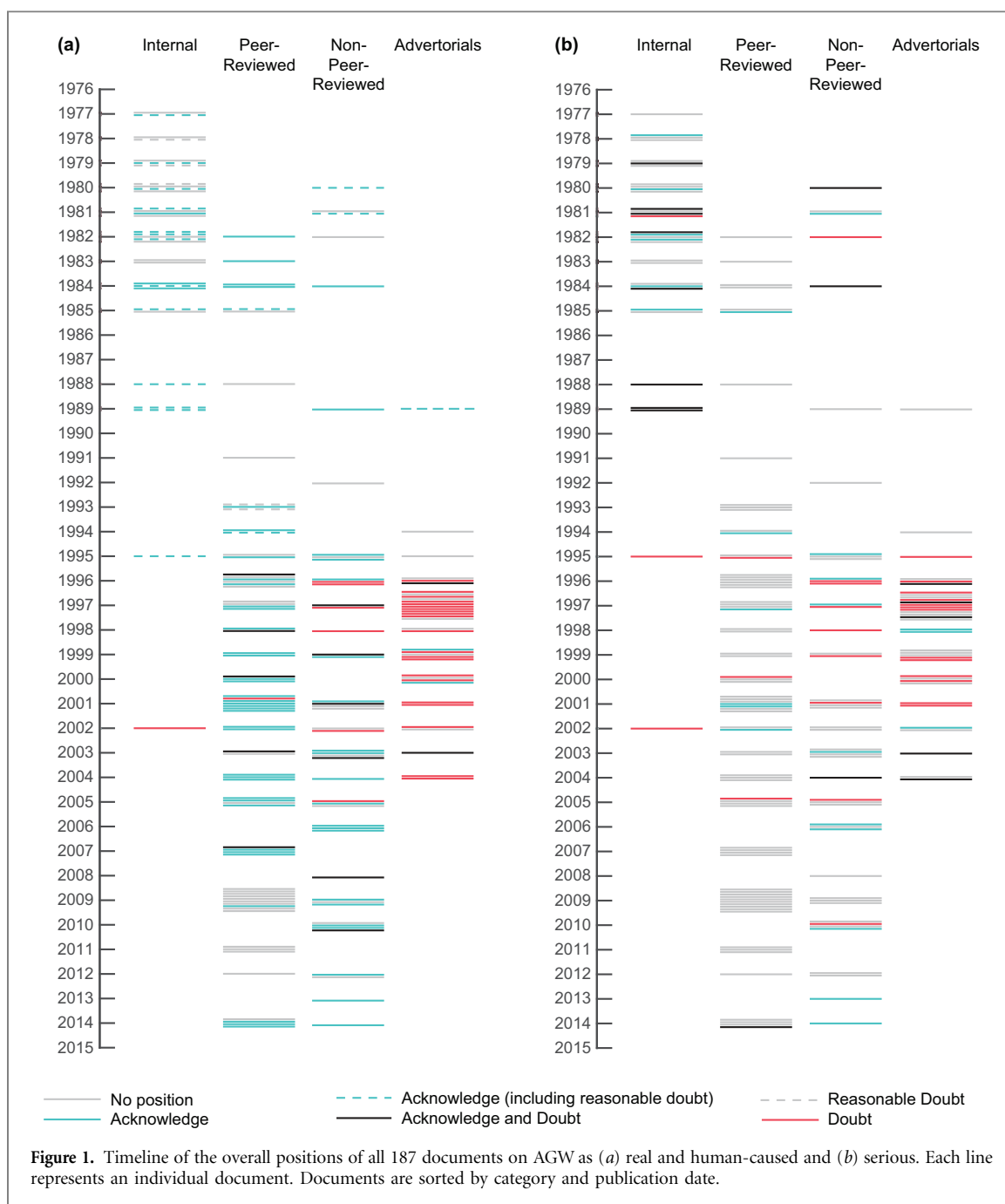
2.1.2. 'Serious'

We assign 'Impact Points' (IP1 to IP3, defined in table 2) throughout each document based on its

positions on AGW as having known or predicted negative impacts (for example, geophysical, economic, or sociopolitical) (intercoder reliability of Impact Points: 94%; Kripp. $\alpha = 0.86$). Each document is then assigned one of four overall Impact Levels (ILs): 'No Position' (all text and figures are IP2 only); 'Acknowledge' (IP1 only); 'Acknowledge and Doubt' (IP1 and IP3); or 'Doubt' (IP3 only) (intercoder reliability of Impact Levels: 89%; Kripp. $\alpha = 0.77$).

2.1.3. 'Solvable'

We identify documents that express 'Doubt' (SP1, defined in table 2) as to whether AGW can be mitigated or whether the costs of doing so exceed the benefits (intercoder reliability: 97%; Kripp. $\alpha = 0.84$). While the question of AGW's solvability is not resolvable on purely technical grounds, the relative extent to which documents promote doubt on the matter remains relevant to the character of climate communications, insofar as assertions that AGW



cannot be stopped are a common component of contrarian claims [42, 72].

2.2. Risks of stranded assets

AGs and the SEC are investigating ExxonMobil's understanding and disclosures of the financial risks related to either AGW or future climate policy, and shareholders have questioned the adequacy of ExxonMobil's disclosures on this point. We examine what, if anything, has been stated on this subject in the documents examined [10, 73–75]. Across all documents, we collate and chronicle ExxonMobil's communications regarding the risks of stranded assets (intercoder reliability: 100%; Kripp. $\alpha = 1.0$). Financial documents from ExxonMobil, such as shareholder

reports, are beyond the scope of this study and a topic for future investigation.

3. Results

3.1. Endorsement levels (ELs)—AGW as real and human-caused

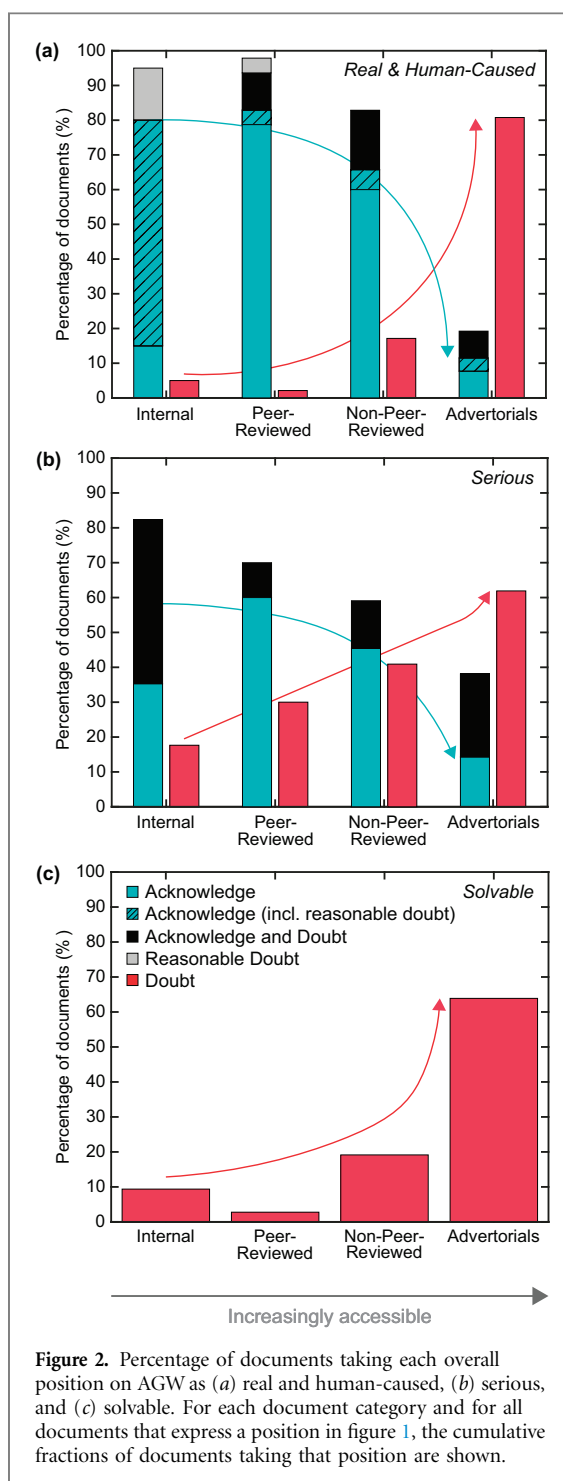
Figure 1(a) is a timeline of the overall positions of all 187 documents on AGW as real and human-caused, sorted by publication date and into four categories: *Internal Documents*, *Peer-Reviewed*, *Non-Peer-Reviewed*, and *Advertorials*. Each line represents an individual document and is color-coded: No position (grey); Acknowledge (blue); Acknowledge and Doubt (black); and Doubt (red). Dashed lines indicate documents that have

Table 3. Example quotations (coding units) expressing (left) acknowledgment and (right) doubt that AGW is real and human-caused. For each document category, two examples are given: the first typifies a relatively ‘strong’ quotation, the second a relatively ‘mild’ one. Substantiating quotations for all documents are provided in section S7, supplementary information.

	Acknowledge AGW is real and human-caused (EP1,2,3)	Doubt AGW is real and human-caused (EP4b-1,2)
INTERNAL	<p>1979 [82] ‘The most widely held theory is that:—The increase [in atmospheric CO₂] is due to fossil fuel combustion;—Increasing CO₂ concentration will cause a warming of the earth’s surface;—The present trend of fossil fuel consumption will cause dramatic environmental effects before the year 2050.’</p> <p>1982 [83] ‘The question of which predictions and which models best simulate a carbon dioxide induced climate change is still being debated by the scientific community. Our best estimate is that doubling of the current concentration could increase average global temperature by about 1.3° to 3.1 °C’</p>	<p>1982 [83] ‘There is currently no unambiguous scientific evidence that the earth is warming. If the earth is on a warming trend, we’re not likely to detect it before 1995.’^a</p> <p>2002 [84] ‘A major frustration to many is the all-too-apparent bias of IPCC to downplay the significance of scientific uncertainty and gaps’</p>
PEER-REVIEWED	<p>1996 [76] ‘The body of statistical evidence . . . now points towards a discernible human influence on global climate.’</p> <p>1995 [86] ‘We present a preliminary analysis of a geoengineering option based on the intentional increase of ocean alkalinity to enhance marine storage of atmospheric CO₂. Like all geoengineering techniques to limit climate change’</p>	<p>2001 [85] ‘A general statistical methodology . . . is proposed as a method for deciding whether or not anthropogenic influences are causing climate change.’</p> <p>2003 [81] ‘Currently, our ability to forecast future climate is in question. Models are used to make projections of future climate, based on scenarios of future human activities and emissions, by simulating each link in the causal chain relating these scenarios to changes in climate. The estimation of the uncertainty of this causal chain remains an important scientific challenge.’</p>
NON-PEER-REVIEWED	<p>1981 [87] ‘The conviction in the scientific community that the observed trend of increasing carbon dioxide, if it continues, will cause a global warming is based on a variety of theoretical studies . . . the results are now fairly consistent. For a carbon dioxide doubling the calculated mean surface-air temperature increase is approximately 2 °C to 3 °C. The warming is 2 to 3 times larger in the northern polar regions . . . Other model-predicted features are shifts of precipitation and soil moisture, retreat of polar snow and sea ice, and changes of large-scale circulation patterns.’</p> <p>2003 [89] ‘. . . a 2 °C warming target (which can still produce adverse climate impacts) requires non-CO₂-emitting primary power in the 10 to 30 TW range by 2050.’</p>	<p>1996 [88] Title: ‘Global warming: who’s right? Facts about a debate that’s turned up more questions than answers.’ ‘. . . a multinational effort, under the auspices of the United Nations, is under way to cut the use of fossil fuels, based on the unproven theory that they affect the earth’s climate.’</p> <p>2008 [90] ‘Nor are [the <i>Oil and Natural Gas Industry Guidelines for Greenhouse Gas Reduction Projects</i>] intended to imply a direct connection between GHG emissions from the oil and natural gas industry and the phenomenon commonly referred to as climate change.’</p>
ADVERTORIALS	<p>1999 [91] ‘Reasonable concerns about the buildup of greenhouse gases in the atmosphere and their effect on earth’s climate have prompted policymakers to search for a response.’</p> <p>2003 [93] ‘We humans are interacting with the geo-chemical systems of our planet on a global scale. The concentration of carbon dioxide in the atmosphere has increased by a third from its preindustrial level, and the resulting change in the acidity of the upper ocean can be detected.’^b</p>	<p>1997 [92] ‘Let’s face it: The science of climate change is too uncertain to mandate a plan of action that could plunge economies into turmoil . . . Scientists cannot predict with certainty if temperatures will increase, by how much and where changes will occur. We still don’t know what role man-made greenhouse gases might play in warming the planet . . . Let’s not rush to a decision at Kyoto. Climate change is complex; the science is not conclusive; the economics could be devastating.’</p> <p>1997 [94] Title: ‘Climate change: a degree of uncertainty.’ ‘. . . there is a high degree of uncertainty over the timing and magnitude of the potential impacts that man-made emissions of greenhouse gases have on climate . . . To address the scientific uncertainty governments, universities and industry should form global research partnerships to fill in the knowledge gap, with the goal of achieving a consensus view on critical issues within a defined time frame’</p>

^a Document filtered by our analysis as reasonable due to pre-1990 publication date.

^b Advertorial is signed by Stanford University Professor Lynn Orr, then-director of Stanford’s Exxon-funded GCEP alliance, and bears the seal of Stanford University. See section S7, supplementary information, for details.



been filtered for reasonable doubt. Table 3 presents exemplifying quotations (coding units) of varying ‘strength’ that illustrate the assigned positions for a selection of the documents. For each category and for all documents that express a position, figure 2(a) shows the cumulative fraction of documents that take that position. Positions on AGW as real and human-caused vary significantly across document categories ($p < 3.7 \times 10^{-13}$, Fisher’s exact test, FET; see table S3, supplementary information, for details and all probability values). Figure 2 is based on all documents in figure 1; the same trend is observed when only documents with an overlapping date range are considered (section S4, supplementary information).

3.1.1. Peer-reviewed publications

Figures 1(a) and 2(a) show that ExxonMobil’s peer-reviewed publications overwhelmingly acknowledge AGW as real and human-caused (‘Acknowledge’). Of the 65% (47/72) of peer-reviewed documents that express a position, more than three-quarters hold an ‘Acknowledge’ position (39/47 = 83%). Table 3 provides sample quotations (see section S7, supplementary information, for substantiating quotations for all documents). ExxonMobil’s listed publications include chapter 8 of the 1995 IPCC report (ExxonMobil’s principal climate scientist, Haroon Khesghi, was a contributing author), which observed a ‘discernible human influence on global climate’ [15, 76]. Khesghi also co-authored the Summary for Policymakers and several chapters of the next IPCC report in 2001, which found ‘there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities’ [77–80]. Of the minority of peer-reviewed documents holding a position of ‘Acknowledge and Doubt’ (5/47 = 11%), ‘Reasonable Doubt’ (2/47 = 4%), or ‘Doubt’ (1/47 = 2%), we judge that most of the expressed doubt constitutes normal scientific discussion about uncertainties; for example, ‘the estimation of the uncertainty of this causal chain [linking human activities to changes in climate]’ [81].

3.1.2. Non-peer-reviewed documents

The predominant stance taken in non-peer-reviewed communications is also ‘Acknowledge’, although compared to peer-reviewed work, it loses ground to the ‘Acknowledge and Doubt’ and ‘Doubt’ stances in roughly equal measure ($p = 0.044$, FET). Figures 1(a) and 2(a) show that, of the 74% (35/47) that take a position, 66% (23/35) ‘Acknowledge’, 17% (6/35) ‘Acknowledge and Doubt’, and 17% (6/35) ‘Doubt’ that AGW is real and human-caused. The more frequent expressions of doubt in non-peer-reviewed documents, compared with peer-reviewed ones, reflect the mixed nature of these documents. Some are technical, academic analyses, while others are industry-targeted speeches, reports, conference proceedings, company pamphlets, etc (see sections S2, S3, and S6, supplementary information).

3.1.3. Internal documents

The bulk of ExxonMobil’s internal documents also take the ‘Acknowledge’ stance. Figures 1(a) and 2(a) show that, of the 63% (20/32) that take a position, 80% (16/20) adopt ‘Acknowledge’, with most of the rest expressing ‘Reasonable Doubt’ (3/20 = 15%). Unlike other document categories, however, our characterization of internal documents shifts dramatically if we remove filters for reasonable doubt from our analysis (see section 2). Then, 61% (11/18) take the mixed position (‘Acknowledge and Doubt’), with the remainder split between ‘Acknowledge’ and ‘Doubt’ (3/18 = 17% and 4/18 = 22%, respectively).

These results are explained by the early publication period of internal documents: all but two were published before the 1990 IPCC report, and are therefore subject to our filters for reasonable doubt. These results also reflect the predominant nature of the internal documents: they acknowledge the likelihood of AGW based on internal and external research, while also highlighting uncertainties.

In 1979, for instance (table 3), an internal Exxon study concluded that:

The most widely held theory is that:

- The increase [in atmospheric CO₂] is due to fossil fuel combustion
- Increasing CO₂ concentration will cause a warming of the earth's surface
- The present trend of fossil fuel consumption will cause dramatic environmental effects before the year 2050.

However, the memo notes: 'It must be realized that there is great uncertainty in the existing climatic models because of a poor understanding of the atmospheric/terrestrial/oceanic CO₂ balance' [82]. Likewise, an internal briefing on the 'CO₂ "Greenhouse" Effect' from 1982 states: 'There is currently no unambiguous scientific evidence that the earth is warming. If the earth is on a warming trend, we're not likely to detect it before 1995' (see table 3). Yet, the authors say, 'Our best estimate is that doubling of the current concentration could increase average global temperature by about 1.3°C to 3.1°C' [83]. Several internal documents make this distinction, acknowledging that increased CO₂ would likely cause warming, while expressing (reasonable) doubt that warming was already underway and large enough to be detected.

This cautious consensus is also evident in charts in internal ExxonMobil presentations and reports. (Due to copyright restrictions prohibiting the reproduction of figures owned by ExxonMobil, we instead provide hyperlinks to third-party websites at which relevant figures can be viewed.) For example, in a 1978 presentation to the Exxon Corporation Management Committee, Exxon scientist James Black showed a graph (see <https://perma.cc/PJ4N-T8SC>) of projected warming 'model[ed] with the assumption that the carbon dioxide levels will double by 2050 A.D.' [95]. Another case is the 1982 Exxon primer already mentioned, which includes a graph (see <https://perma.cc/PH4X-ZJBA>) showing 'an estimate of the average global temperature increase' under the 'Exxon 21st Century Study-High Growth scenario' [83]. A third example is a table (see <https://perma.cc/9DGQ-4TBW>) presented by Exxon scientist Henry Shaw at a 1984 Exxon/Esso environmental conference, which showed that Exxon's expected 'average temper-

ature rise' of 1.3°C–3.1°C was comparable to projections by leading research institutions (1.5°C–4.5°C) [96]. This shows that ExxonMobil scientists and managers were well informed of the state of the science at the time. But they also tended to focus on the prevailing uncertainties: Black stressed the alleged shortcomings of extant climate models before showing his results; Shaw emphasized the variable and 'unpredictable' character of some values.

We conclude that ExxonMobil's recent defense accurately characterizes the situation with respect to its peer-reviewed, non-peer-reviewed, and internal documents: 'Our researchers recognized the developing nature of climate science at the time . . . [and] mirrored global understanding' [14]. On several occasions during the early 1980s, the company's peer-reviewed and internal documents went as far as to refute 'calculations on a more limited scale by a number of climatologists' that projected much less global warming than the rest of the scientific community, including ExxonMobil [97–99]. 'In summary,' said a 1982 memo, 'the results of our research are in accord with the scientific consensus on the effect of increased atmospheric CO₂ on climate . . . and are subject to the same uncertainties' [99]. As a scientific consensus emerged in the early 1990s that AGW was underway, a 1995 'Primer on Climate Change Science' co-authored by Mobil as part of the Global Climate Coalition explicitly rejected contrarian claims that were beginning to circulate: 'Contrarian theories . . . do not offer convincing arguments against the conventional model of greenhouse gas emission-induced climate change' [100].

3.1.4. Advertorials

The predominant stance taken in ExxonMobil's advertorials is 'Doubt'. In essence, these public statements reflect only the 'Doubt' side of ExxonMobil's mixed internal dialogue. Figures 1(a) and 2(a) show that of the 72% (26/36) of climate change advertorials that take a position, 81% (21/26) take the position of 'Doubt', with the remainder split between 'Acknowledge' (3/26 = 11.5%) and 'Acknowledge and Doubt' (2/26 = 7.5%). A characteristic example is a 1997 Mobil advertorial (table 3), which stated: 'Let's face it: The science of climate change is too uncertain to mandate a plan of action that could plunge economies into turmoil . . . Scientists cannot predict with certainty if temperatures will increase, by how much and where changes will occur. We still don't know what role man-made greenhouse gases might play in warming the planet' [92]. Another, also from 1997, referred to a 'high degree of uncertainty,' 'debate,' and a 'knowledge gap,' and the need for further 'fact-finding' and 'additional knowledge' before UN negotiators in Kyoto could make decisions [94]. The advertorial stressed the goal 'of achieving a consensus view,' two years after the IPCC had presented one.

Our analysis is limited to advertorials in the *NYT* because those pertaining to climate change have already been compiled and are readily available. Brown *et al* report that ExxonMobil also ran advertorials in eight other major newspapers [19]. Some of these appear to have been the same or similar to those in the *NYT*. For example, in an advertorial in *The Washington Post* in 2000, ExxonMobil criticized a US National Assessment report on climate change as putting the ‘political cart before a scientific horse’ and being based ‘on unreliable models’ [101]. The advertorial was condemned by the former director of the National Assessment Coordination Office: ‘To call ExxonMobil’s position out of the mainstream is . . . a gross understatement’ [102].

3.1.5. Contrast between advertorials and other documents

Our analysis shows that ExxonMobil’s scientists and executives were, for the most part, aware and accepting of the evolving climate science from the 1970s onwards, but they painted a different picture in advertorials. The majority of ExxonMobil’s peer-reviewed publications acknowledge that climate change is real and human-caused, and internal documents reflect this scientific framework. Uncertainties are mentioned or even highlighted, but usually in the context of broader scientific understandings and broadly consistent with the evolving science. In contrast, ExxonMobil’s advertorials overwhelmingly focus on the uncertainties, casting doubt on the growing scientific consensus (e.g. peer-reviewed publications versus advertorials: $p = 4.1 \times 10^{-13}$, FET).

The contrast between advertorials and other documents is particularly evident in their accompanying figures. For instance, in a chapter of a 1985 US Department of Energy report co-authored by Exxon scientist Brian Flannery [103], a graph (see <https://perma.cc/A5WN-LKLS>) presents the results of future warming modeled for different CO₂ scenarios. ‘The foregoing results, with all their caveats,’ the report summarizes, ‘can be construed as an approximate bracketing of the consensus of transient model predictions for the next century’s CO₂ greenhouse effect. In this restricted sense, they are consistent with the EPA’s estimate of a 2 °C warming from fossil fuel CO₂ and other greenhouse gases by the middle of the next century.’ Their conclusion is entitled ‘Consensus CO₂ Warming.’ Compare this with figures from ExxonMobil advertorials in 1997 and 2000 (see <https://perma.cc/39CC-JTES> and <https://perma.cc/74BL-KL8A>, respectively), which downplay the human contribution to AGW and emphasize natural variability instead [104, 105]. Featured in an advertorial entitled ‘Unsettled Science’ in the *NYT* and *The Wall Street Journal*, the latter figure was taken from an article in *Science*

by Lloyd Keigwin of the Woods Hole Oceanographic Institution [105–107]. Keigwin called the use of his data ‘very misleading’ [106]. They were a historical reconstruction of sea-surface temperatures in the Sargasso Sea and, in his words, ‘not representative of the planet as a whole [as the advertorial could be taken to imply]. To jump from the western North Atlantic Ocean to the globe is something no responsible scientist would do . . . There’s really no way those results bear on the question of human-induced climate warming . . .’

The contrast across document categories is also clear when analyzed at a year-to-year scale (figure 1(a)). The majority of advertorials promoting doubt follow a decade of numerous acknowledgments in the other three document categories. Between 1977 and 1996, of all peer-reviewed, non-peer-reviewed, and internal documents that take a position, 83% fully or partly (81% and 2%, respectively) acknowledge that AGW is real and human-caused (if we remove our filter for reasonable doubt, still 83% fully or partly (43% and 40%, respectively) acknowledge this). Thereafter, in 1997 alone, we see nine advertorials promoting ‘Doubt’. Significantly, throughout the late 1990s and early 2000s, ExxonMobil peer-reviewed publications and advertorials in the same years contradict one another (figure 1(a)).

3.2. Impact levels (ILs)—AGW as serious

Figure 1(b) is a timeline of the overall positions of all 187 documents on AGW as serious. For each category of document and for all documents that express a position, figure 2(b) shows the cumulative fraction of documents that take that position. Positions on AGW as serious vary significantly across document categories ($p = 0.11$, FET).

3.2.1. Peer-reviewed publications

ExxonMobil’s 72 peer-reviewed publications focus almost exclusively on methods and mitigation (section S3, supplementary information). Only 10 discuss the potential impacts of AGW (figure 1(b)), of which 60% (6/10) take a position of ‘Acknowledge’, 30% (3/10) of ‘Doubt’, and 10% (1/10) of ‘Acknowledge and Doubt’ (figure 2(b)). Hoffert *et al* (2002), for example (see table 4), warned that unchecked greenhouse gas emissions ‘could eventually produce global warming comparable in magnitude but opposite in sign to the global cooling of the last Ice Age . . . Atmospheric CO₂ stabilization targets as low as 450 ppm could be needed to forestall coral reef bleaching, thermohaline circulation shutdown, and sea level rise from disintegration of the West Antarctic Ice Sheet’ [108]. A 1994 paper defined ‘mean global warming of 2 °C from preindustrial time to 2100 as *Illustrative Reference Values* for climate and ecosystem protection,’ two years before the EU adopted this limit [109, 110].

Table 4. Example quotations (coding units) expressing (left) acknowledgment and (right) doubt that AGW is serious. For each document category, two examples are given: the first typifies a relatively ‘strong’ quotation, the second a relatively ‘mild’ one. Substantiating quotations for all documents are provided in section S7, supplementary information.

	Acknowledge AGW is serious (IP1)	Doubt AGW is serious (IP3)
INTERNAL	<p>1982 [83] ‘... there are some potentially catastrophic events that must be considered. For example, if the Antarctic ice sheet[,] which is anchored on land should melt, then this could cause a rise in sea level on the order of 5 meters. Such a rise would cause flooding on much of the US East Coast, including the State of Florida and Washington, DC.’</p> <p>1982 [99] ‘There is unanimous agreement in the scientific community that a temperature increase of this magnitude [(3.0 ± 1.5)°C] would bring about significant changes in the earth’s climate, including rainfall distribution and alterations in the biosphere.’</p>	<p>1981 [111] ‘... it has not yet been proven that the increases in atmospheric CO₂ constitute a serious problem that requires immediate action.’</p> <p>1989 [113] ‘We also know that the modeled projections are far from certain: potential impacts could be small and manageable or they could be profound and irreversible.’</p>
PEER-REVIEWED	<p>2002 [108] ‘Atmospheric CO₂ has increased from ~275 to ~370 parts per million (ppm). Unchecked, it will pass 550 ppm this century. Climate models and paleoclimate data indicate that 550 ppm, if sustained, could eventually produce global warming comparable in magnitude but opposite in sign to the global cooling of the last Ice Age ... Atmospheric CO₂ stabilization targets as low as 450 ppm could be needed to forestall coral reef bleaching, thermohaline circulation shutdown, and sea level rise from disintegration of the West Antarctic Ice Sheet.’</p> <p>1994 [109] ‘The rate of the climate change is thought to exert stress on ecosystems. While changes in, for example, precipitation or infrequent events such as droughts or storms may be more directly related to this stress, there remains great uncertainty in estimating these characteristics of climate.’</p>	<p>2000 [114] ‘... science cannot yet provide reliable guidance on what, if any, levels of greenhouse gas concentrations might be judged “dangerous,” ...’</p> <p>1995 [86] ‘Among the options that might become necessary to deploy at some time in the future, should climate change prove to be serious, are those that involve geoengineering techniques to control greenhouse gas concentrations or to limit potential impacts.’</p>
NON-PEER-REVIEWED	<p>1984 [115] ‘Clearly, there is vast opportunity for [global] conflict. For example, it is more than a little disconcerting the few maps showing the likely effects of global warming seem to reveal the two superpowers losing much of the rainfall, with the rest of the world seemingly benefitting.’</p> <p>1980 [117] ‘Findings. 1. While CO₂-induced changes in global climate may have certain beneficial effects, it is believed that the net consequences of these changes will be adverse to the stability of human and natural communities.’</p>	<p>1996 [116] ‘Is global warming good or bad? Let’s say human activity <i>does</i> contribute to warming the planet ... warming that occurs mostly during the winter would reduce extreme cold, increase cloud cover and moderate temperature fluctuations. This sort of warming is more likely to raise soil moisture levels than to produce severe droughts ... [T]he indications are that a warmer world would be far more benign than many imagine ... [M]oderate warming would reduce mortality rates in the US, so a slightly warmer climate would be more healthful ... We are faced with more questions than answers on almost every aspect of this issue, including whether possible changes could be both good and bad.’</p> <p>1998 [118] ‘Fortunately, all indications are that climate change is a very long-term phenomenon ... Do we need an insurance policy? Some people argue that the world needs to take out an insurance policy against the possibility of global warming just in case ... Because of the scientific uncertainties, we don’t have a clear understanding of the risks involved. The Kyoto agreement makes the cost of the policy high. No one can tell us with certainty what benefit we will gain. Thus, it doesn’t seem to be a good time to buy the policy.’</p>
ADVERTORIALS	<p>2002 [119] ‘The risk of climate change and its potential impacts on society and the ecosystem are widely recognized. Doing nothing is neither prudent nor responsible.’</p> <p>2004 [120] ‘... research has highlighted the risks to society and ecosystems resulting from the buildup of greenhouse gases.’</p>	<p>1995 [112] Title: ‘The sky is not falling.’ By-line: ‘The environment ... better than you think.’</p> <p>2000 [121] ‘Good news: The end of the Earth as we know it is not imminent ... [M]ore than 30 years have passed since the environmental movement began. They made their point. There is no longer a need for alarmists ... [T]o those who think industry and nature cannot coexist, we say show a little respect for Mother Nature. She is one strong lady, resilient and capable of rejuvenation. The environment recovers well from both natural and man-made disasters ... Does this justify or lessen the impact of industrial pollution? Of course not. Our point is that nature, over the millennia, has learned to cope. Mother Nature is pretty successful in taking on human nature.’</p>

3.2.2. Non-peer-reviewed publications

Non-peer-reviewed documents offer a mix of positions (figures 1(b) and 2(b)). Among the 47% (22/47) that take a position, 45% (10/22) 'Acknowledge', 41% (9/22) 'Doubt', and 14% (3/22) 'Acknowledge and Doubt'. As with Endorsement Levels, several of the expressions of doubt in non-peer-reviewed documents reflect the industry-targeted communications included in this category (see sections S2, S3, and S6, supplementary information).

3.2.3. Internal documents

Internal documents typically acknowledge the potential for serious impacts but also highlight uncertainties. Of the 53% (17/32) of documents with a position, 35% (6/17) 'Acknowledge' and 47% (8/17) 'Acknowledge and Doubt' (figure 2(b)). A characteristic acknowledgement is found in a 1980 Exxon memo, which says, 'There are some particularly dramatic questions that might cause serious global problems. For example, if the Antarctic ice sheet[,] which is anchored on land, should melt, then this could cause a rise in the sea level on the order of 5 meters. Such a rise would cause flooding in much of the US East Coast including the state of Florida and Washington D.C.' [98] (see also [83]). An example of doubt is a 1981 report stating 'that it has not yet been proven that the increases in atmospheric CO₂ constitute a serious problem that requires immediate action' [111] (table 4).

3.2.4. Advertorials

In contrast, ExxonMobil advertorials overwhelmingly take the position of doubt (e.g. peer-reviewed publications versus advertorials: $p = 0.045$, FET). Of the 58% (21/36) of advertorials that take a position, 62% (13/21) express 'Doubt' (figure 2(b)). Most of the remainder express a mixed position (5/21 = 24%). Often, they express the opinion that concern over climate impacts is alarmist, such as a 1995 advertorial entitled 'The sky is not falling,' which asserted, 'The environment recovers well from both natural and man-made disasters' [112] (table 4).

3.3. Solvable Levels (SLs)—AGW as solvable

Positions on AGW as solvable vary significantly across document categories ($p = 3.4 \times 10^{-12}$, FET). Figure 2(c) shows that only 3% (2/72) of peer-reviewed papers express doubt that AGW is solvable. Internal and non-peer reviewed materials also express relatively low levels of doubt: 9% (3/32) and 19% (9/47), respectively. In contrast, 64% (23/36) of advertorials do so (e.g. peer-reviewed publications versus advertorials: $p = 2.8 \times 10^{-12}$, FET).

The 'Doubt' arguments are relatively consistent across document categories (table 5), typically suggesting that climate mitigation strategies will either fail or create bigger problems. The arguments point to one or more of: limitations of renewable energy and

other technologies such as carbon capture and storage; an (alleged) dichotomy between climate mitigation and poverty reduction; and potential adverse economic impacts of mitigation. However, there is a discernible difference in the prominence and emphasis that these concerns are given in advertorials compared to other documents. In particular, in advertorials, the remedies for AGW are presented as a grave threat, whereas climate change itself is not. For example, advertorials claimed that the Kyoto Protocol to the United Nations Framework Convention on Climate Change would be 'financially crippling' and 'economy-wrecking' [122, 123]. It, or strategies like it, would lead to 'severe dislocations throughout the world economy,' an 'unprecedented transfer of wealth,' and be a 'blow to US prosperity' [124–126]. One 1997 advertorial warns: 'Flexibility will be constrained. Carpooling in; sport utility vehicles out. High fuel and electric bills. Factory closures. Job displacement. And could businesses and consumers cut their energy consumption by 30 percent without some form of tax or carbon rationing? Probably not' [92]. A 2000 advertorial contrasts the unpredictability of AGW against the asserted 'certainty that climate change policies, unless properly formulated, will restrict life itself' [121] (table 5).

3.4. Stranded fossil fuel assets

The number of times the concept of stranded fossil fuel assets is mentioned varies significantly across document categories ($p = 0.0042$, FET). In total, 24 of the analyzed documents allude to the concept of stranded fossil fuel assets: seven peer-reviewed publications, ten non-peer-reviewed publications, and seven internal documents. No advertorials address the issue.

Stranded assets are discussed in two ways (see table 6 and section S5, supplementary information): (i) Implicit, qualitative connections between fossil fuel reserves/resources/use and either greenhouse gas limits or possible climate mitigation policies; and (ii) explicit quantifications of 'cumulative emissions' and/or 'carbon budgets' consistent with greenhouse gas stabilization.

3.4.1. Qualitative connections

These discussions imply limitations on fossil fuel use because of greenhouse gas limits or climate mitigation. 'Mitigation of the "greenhouse effect"', says the 1982 internal Exxon primer, 'would require major reductions in fossil fuel combustion' [83]. Likewise, an internal 1979 Exxon study found that 'should it be deemed necessary to maintain atmospheric CO₂ levels to prevent significant climatic changes . . . coal and possibly other fossil fuel resources could not be utilized to an appreciable extent' [82].

3.4.2. Quantitative carbon budgets

These discussions introduce, with varying degrees of detail, ideas of 'cumulative fossil fuel use,' 'cumulative

Table 5. Example quotations (coding units) expressing doubt that AGW is solvable. For each document category, two examples are given: the first typifies a relatively ‘strong’ quotation, the second a relatively ‘mild’ one. Substantiating quotations for all documents are provided in section S7, supplementary information.

Doubt AGW is solvable (SP1)		
INTERNAL	1989 [131]	‘Some key perceptions/misconceptions . . . Nuclear and/or renewable energy resources can solve the problem.’
	1982 [83]	‘Making significant changes in energy consumption patterns now to deal with this potential problem amid all the scientific uncertainties would be premature in view of the severe impact such moves could have on the world’s economies and societies.’
PEER-REVIEWED	2002 [108]	‘Even as evidence for global warming accumulates, the dependence of civilization on the oxidation of coal, oil, and gas for energy makes an appropriate response difficult.’
	2001 [132]	‘Even for the higher stabilization levels considered, the developing world would not be able to use fossil fuels for their development in the manner that the developed world has used them.’
NON-PEER-REVIEWED	1998 [118]	‘To get to the [Kyoto] target, we would have to stop all driving in the US or close all electric power plants or shut down every industry. Obviously, these are not realistic options . . . meeting the Kyoto target would clearly have a huge economic impact.’ ‘Independent economists project that to get the targeted reductions in fossil-fuel use, price increases like these would be required: 40 percent for gasoline, 50 percent for home heating oil, 25 percent for electricity and 50 percent for natural gas. These and other price hikes could cost the average American family of four about \$2,700 a year. At least some developed countries would probably have to impose significantly higher fossil fuel taxes, rationing or both.’
	2005 [133]	‘[E]missions will continue to grow to meet the demands of society for prosperity and to meet basic needs . . . Countries like India, China and Indonesia are going to rely on domestic coal to meet growing needs . . . and their emissions are going to grow rapidly . . . [F]ossil fuels will remain the dominant source of energy supply over this period and beyond. Even with rapid year-to-year growth, intermittent renewable energy from wind and solar will remain a small contributor to global energy needs.’
ADVERTORIALS	1997 [92]	‘What is not moderate is the call [by the US government and other countries in the run up to UN Kyoto negotiations] to lower emissions to 1990 levels. A cutback of that size would inflict considerable economic pain . . . Committing to binding targets and timetables now will alter today’s lifestyles and tomorrow’s living standards. Flexibility will be constrained. Carpooling in; sport utility vehicles out. High fuel and electric bills. Factory closures. Job displacement. And could businesses and consumers cut their energy consumption by 30 percent without some form of tax or carbon rationing? Probably not.’
	2002 [134]	‘On an overall basis, many of today’s suggested alternative energy approaches are not as energy efficient, environmentally beneficial or economic as competing fossil fuels. They are often sustained only through special advantages and government subsidies. This is not a desirable basis for public policy or the provision of energy.’

CO₂ emissions,’ and ‘carbon budgets . . . for CO₂ stabilization’ and/or climate mitigation [81, 127]. Five of these ExxonMobil studies—one internal, three peer-reviewed, and one non-peer-reviewed—include data (see, for example, <https://perma.cc/EJ5A-EAZ7>) that indicate 2015–2100 CO₂ budgets consistent with limiting warming to 2 °C and/or stabilizing CO₂ concentrations below 550 ppm in the range of 251–716 GtC [81, 83, 127–129]. These budgets are within a factor of two of contemporary estimates of roughly 442–651 GtC [130] (see caption, table 6).

4. Discussion

The question we have addressed in this study is not whether ExxonMobil ‘suppressed’ climate change research, ‘withheld’ it, or ‘sought to hide’ it, which is how ExxonMobil has glossed the allegations against it [11, 12, 135]. This is also how the allegations have occasionally been presented in the press [136]. Our assessment of ExxonMobil’s peer-reviewed publica-

tions and the role of its scientists supports the conclusion that the company did not ‘suppress’ climate science—indeed, it contributed to it.

However, on the question of whether ExxonMobil misled non-scientific audiences about climate science, our analysis supports the conclusion that it did. This conclusion is based on three factors: discrepancies in AGW communications between document categories; imbalance in impact of different document categories; and factual misrepresentations in some advertorials.

First, we have shown that there is a discrepancy between what different document categories say, and particularly what they emphasize, about AGW as real, human-caused, serious, and solvable. This discrepancy grows with the public accessibility of documents, and is greatest between advertorials and the other documents.

Second, in public, ExxonMobil contributed quietly to the science and loudly to raising doubts about it. ExxonMobil’s peer-reviewed and non-peer-reviewed publications have been cited an average (median (mean)) of 21(60) and 2(9) times, respectively,

Table 6. Example quotations (coding units) alluding to stranded fossil fuel assets. For each document category except advertorials, which do not discuss stranded assets, two examples are given: the first typifies an implicit, qualitative connection between fossil fuel reserves/resources/use and either greenhouse gas limits or possible climate mitigation policies; the second is characteristic of an explicit quantification of ‘cumulative emissions’ and/or ‘carbon budgets’ consistent with greenhouse gas stabilization. These quantitative examples are comparable to contemporary estimates; specifically, the IPCC indicates a carbon budget of 442 GtC (or 651 GtC) between 2015 and 2100 for limiting CO₂-induced AGW to below 2 °C relative to 1861–1880 with a probability greater than 66% (or 50%) [130]. Quotations from all 24 documents that refer to stranded assets are provided in section S5, supplementary information.

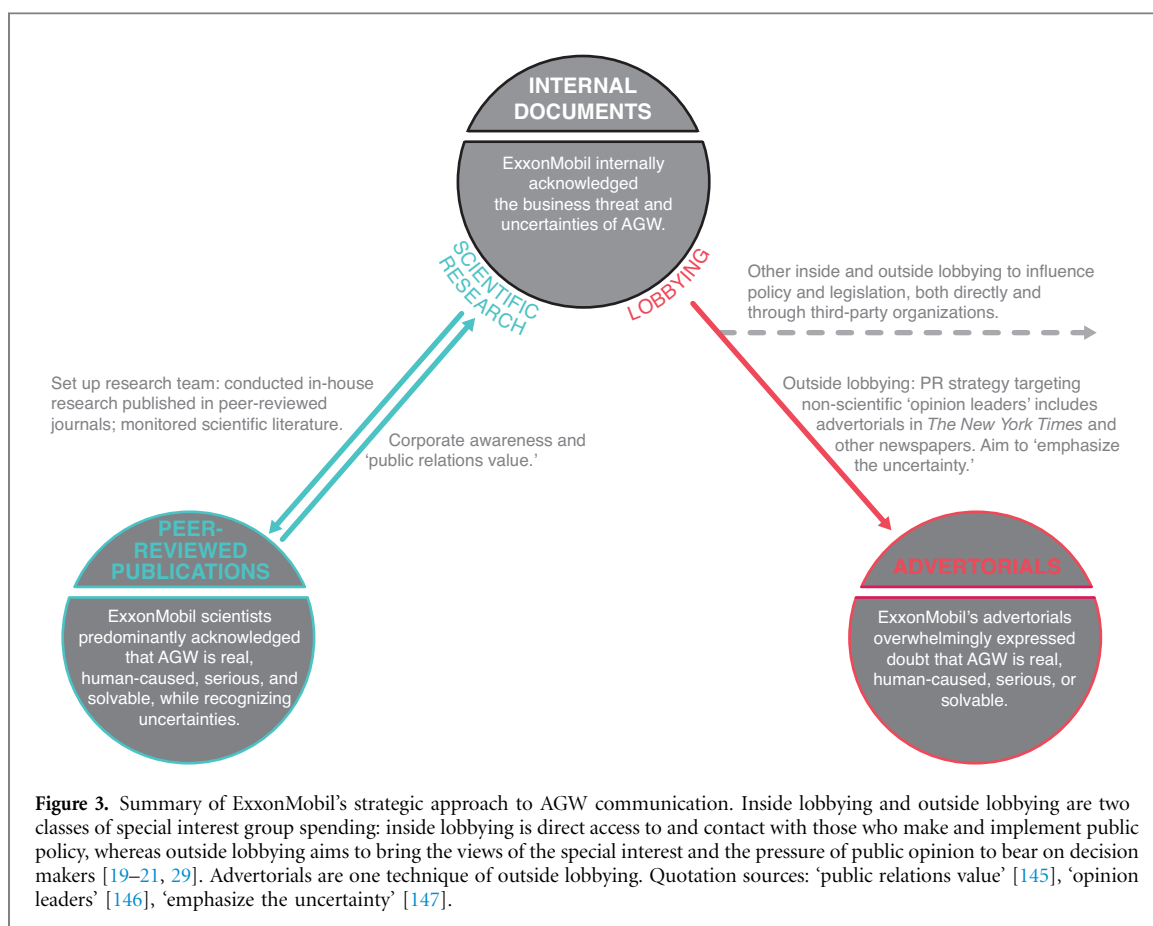
INTERNAL	1979 [82]	‘The major conclusion from this report is that, should it be deemed necessary to maintain atmospheric CO ₂ levels to prevent significant climatic changes, dramatic changes in patterns of energy use would be required. World fossil fuel resources other than oil and gas could never be used to an appreciable extent . . . Removal of CO ₂ from flue gases does not appear practical due to economics and lack of reasonable disposal methods. If it becomes necessary to limit future CO ₂ emissions without practical removal/disposal methods, coal and possibly other fossil fuel resources could not be utilized to an appreciable extent.’
	1982 [83]	‘Table 4 presents the estimated total quantities of CO ₂ emitted to the environment as GtC, the growth of CO ₂ in the atmosphere in ppm (v), and average global temperature increase in °C over 1979 as the base year.’ (Note that temperature anomalies appear to be calculated based on equilibrium climate sensitivity.) It also shows ‘cumulative’ CO ₂ ‘emitted, GtC’ as a function of time. Given roughly 0.3 °C warming by 1979 relative to 1861–1880, we read off (by interpolation) the cumulative emissions in table 4 (in [83]) corresponding to a further 1.7 °C warming, yielding a carbon budget for <2 °C of 624 GtC. Adjusting for emissions between 1979 and 2015, we obtain a carbon budget for <2 °C of 373 GtC between 2015 and 2100, which is comparable with contemporary estimates of roughly 442–651 GtC (see caption).
PEER-REVIEWED	1985 [103]	‘More complex scenarios . . . can be envisioned in which fossil fuel use is rapidly phased out by taxing or other policies, or in which fossil fuel use is decreased by societal feedbacks based on observations of global warming.’
	2003 [81]	Figure 9 (in [81]) shows that temperature anomalies of less than or equal to 2 °C (note that these appear to be calculated based on equilibrium climate sensitivity) are consistent with CO ₂ stabilization at concentrations of 450 ppm or 550 ppm. Table 3 (in [81]) explicitly quantifies fossil fuel ‘carbon budgets . . . for CO ₂ stabilization’ at these concentrations, with reference values of 485 GtC (450 ppm scenario) and 820 GtC (550 ppm scenario) between 2000 and 2099. Adjusting for emissions between 2000 and 2015, this yields carbon budgets for <2 °C of 357 GtC and 692 GtC, respectively, between 2015 and 2100, which are comparable with contemporary estimates of roughly 442–651 GtC (see caption).
NON-PEER-REVIEWED	2005 [133]	‘Without obligations by developing countries, stabilizing at 550 ppm would require a phase out in the use of fossil fuels by the middle of the century in the annex 1 countries. That’s a huge step.’
	2003 [129]	Author introduces the idea of ‘cumulative fossil fuel use’ and ‘cumulative CO ₂ emissions.’ Figure 3 (in [129]) shows that a ‘550 ppm stabilization trajectory’ requires a rapid decline in annual CO ₂ emissions, with cumulative emissions between 2015 and 2100 (integrating area beneath curve) of roughly 490 GtC. This is comparable to contemporary carbon budget estimates for <2 °C of roughly 442–651 GtC (see caption). Author also notes that ‘cumulative fossil fuel use of 2000 GtC might not exhaust global fossil fuel reserves, but limits to fossil fuel use might be driven by better alternatives that emerge over the next century.’ He refers to ‘notional scenarios for a fossil fuel era of limited duration.’

suggesting an average readership of tens to hundreds³. Most texts are highly technical, intellectually inaccessible for laypersons, and of little interest to the general public or policymakers. Most scientific journals and conference proceedings are only circulated to academic libraries and require a paid subscription, making them physically inaccessible for the general public, too. Obtaining academic documents for this study, for example, required access to libraries at Harvard University and Massachusetts Institute of Technology and international interlibrary loans. By contrast, Mobil/ExxonMobil bought AGW advertorials in the *NYT* specifically to allow ‘the public to know where we stand’ [137]. Readerships were in the millions [29]. The company took out an advertorial

every Thursday between 1972 and 2001 [29]. They paid a discounted price of roughly \$31 000 (2016 USD) per advertorial and bought one-quarter of all advertorials on the Op-Ed page, ‘towering over the other sponsors’ according to reviews of Mobil’s advertorials by Brown, Waltzer, and Waltzer [19, 29]. ‘After [experimentally] examining the effects of an actual ExxonMobil advertorial that appeared on the pages of *The New York Times*,’ Cooper and Nownes observed ‘that advertorials substantially affect levels of individual issue salience . . .’ [20]

Third, ExxonMobil’s advertorials included several instances of explicit factual misrepresentation. As discussed in section 3.1.5, an ExxonMobil advertorial in 2000 directly contradicted the IPCC and presented ‘very misleading’ data, according to the scientist who produced the data [105, 106]. Another advertorial, in 1996, claimed that ‘greenhouse-gas emissions, which have a warming effect, are offset by another

³ Citation counts were sourced predominantly from Google Scholar and, when occasionally not available there, from Web of Science. IPCC reports and a handful of non-applicable documents, such as drafts, were excluded.



combustion product–particulates—which leads to cooling' [138]. In 1985, ExxonMobil scientists had reported being 'not very convinc[ed]' by the argument that 'aerosol particulates . . . compensat[e] for, and may even overwhelm, the fossil-fuel CO₂ greenhouse warming' [103]. By 1995, the IPCC had rejected it [71].

We acknowledge that textual analysis is inherently subjective: words have meaning in context. Particular coding assignments may therefore be debatable, depending on how the meaning and context of individual quotations and figures are interpreted. However, the intercoder reliability and agreement of our content analyses are consistently high (section S1.7, supplementary information). While one might disagree about the interpretation of specific words, the overall trends between document categories are clear (table S3, supplementary information).

In figure 3, we summarize ExxonMobil's strategic approach to AGW research and communication. Internal documents show that by the early 1980s, ExxonMobil scientists and managers were sufficiently informed about climate science and its prevailing uncertainties to identify AGW as a potential threat to its business interests. This awareness apparently came from a combination of prior research and expert advice. For example, in 1979 and 1980, university researcher Andrew Callegari co-authored two peer-reviewed articles acknowledging that 'the climatic implications of fossil fuel carbon dioxide emissions have been recognized for some time' [139, 140]. The

authors articulated the 'climatically huge' temperature increases and ecological impacts that would result 'if a significant fraction of the fossil fuel reserve is burned' (section S5, supplementary information). In 1980, Callegari joined Exxon, and the next year took over its CO₂ research efforts [141]. His papers were frequently cited in company publications [97, 142–144].

Around this time, ExxonMobil set up two parallel initiatives: climate science research, and a complementary public relations campaign (left and right branches of figure 3). According to a 1978 'Request for a credible scientific team,' these initiatives targeted four audiences: the scientific community, government, Exxon management, and the general public and policymakers [145].

4.1. Scientific community

From approximately 1979 to 1982, the Exxon Research and Engineering (ER&E) Company pursued three major AGW research projects. ExxonMobil's 2015 statement that two of the projects 'had nothing to do with CO₂ emissions' [148] is contradicted by internal documents [111, 149, 150]. In the early 1980s, these major research initiatives were discontinued amidst budget cuts [111, 151]. In 1984, ER&E characterized its approaches: 'Establish a scientific presence through research program in climate modeling; selective support of outside activities; maintain awareness of new scientific developments' [152]. In 1986, scientist Haroon Kheshgi joined ER&E [153], and was

henceforth ExxonMobil's principal (and only consistent) academic author, co-authoring 72% (52/72) of all analyzed peer-reviewed work (79% since his hiring). Indeed, the metadata title of the 'Exxon Mobil Contributed Publications' file is 'Haroon's CV' [15].

4.2. Government

As a 1980 'CO₂ Greenhouse Communications Plan' explained, 'The research is . . . significant to Exxon since future public decisions aimed at controlling the buildup of atmospheric CO₂ could impose limits on fossil fuel combustion' [146]. The scientific research, a 1982 letter described, helped 'to provide Exxon with the credentials required to speak with authority in this area' [99]. ExxonMobil appealed to its research credentials in communications with government officials [84].

4.3. Exxon management

A 1981 'Review of Exxon climate research' observes that 'projects underway and planned on CO₂ . . . are providing an opportunity for us to develop a detailed understanding of the total Federal atmospheric CO₂ program which the Corporation needs for its own planning . . .' [111].

4.4. Public and policymakers

The company's climate science research offered 'great public relations value,' observed a 1978 memo [145]. In 1980, with input from outside public relations counsel, Exxon developed a 'CO₂ Greenhouse Communications Plan,' including advertorials, to target 'opinion leaders who are not scientists' [146, 147]. By 1988–9, this plan explicitly aimed to 'extend the science' and 'emphasize the uncertainty in scientific conclusions regarding the potential enhanced Greenhouse effect' [131, 147]. That year, 1989, they ran their first AGW advertorial. ExxonMobil's interest in influencing the non-scientific public and policymakers helps explain our key observation: the discrepancy between internal and academic documents versus advertorials concerning AGW as real, human-caused, serious, and solvable.

5. Conclusion

Available documents show a discrepancy between what ExxonMobil's scientists and executives discussed about climate change privately and in academic circles and what it presented to the general public. The company's peer-reviewed, non-peer-reviewed, and internal communications consistently tracked evolving climate science: broadly acknowledging that AGW is real, human-caused, serious, and solvable, while identifying reasonable uncertainties that most climate scientists readily acknowledged at that time. In contrast, ExxonMobil's advertorials in the NYT

overwhelmingly emphasized only the uncertainties, promoting a narrative inconsistent with the views of most climate scientists, including ExxonMobil's own. This is characteristic of what Freudenberg *et al* term the *Scientific Certainty Argumentation Method* (SCAM)—a tactic for undermining public understanding of scientific knowledge [57, 58]. Likewise, the company's peer-reviewed, non-peer-reviewed, and internal documents acknowledge the risks of stranded assets, whereas their advertorials do not. In light of these findings, we judge that ExxonMobil's AGW communications were misleading; we are not in a position to judge whether they violated any laws.

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