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

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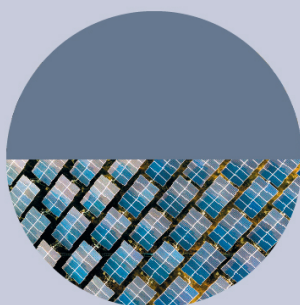
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ADDENDUM

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Addendum to ‘Assessing ExxonMobil’s climate change communications (1977–2014)’ Supran and Oreskes (2017 *Environ. Res. Lett.* **12** 084019)

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Abstract

In our 2017 study ‘Assessing ExxonMobil’s climate change communications (1977–2014)’, we concluded that ExxonMobil has in the past misled the public about climate change. We demonstrated that ExxonMobil ‘advertorials’—paid, editorial-style advertisements—in *The New York Times* spanning 1989–2004 overwhelmingly expressed doubt about climate change as real and human-caused, serious, and solvable, whereas peer-reviewed papers and internal reports authored by company employees by and large did not. Here, we present an expanded investigation of ExxonMobil’s strategies of denial and delay. Firstly, analyzing additional documents of which we were unaware when our original study was published, we show that our original conclusion is reinforced and statistically significant: between 1989–2004, ExxonMobil advertorials overwhelmingly communicated doubt. We further demonstrate that (i) Mobil, like Exxon, was engaged in mainstream climate science research prior to their 1999 merger, even as Mobil ran advertorials challenging that science; (ii) Exxon, as well as Mobil, communicated direct and indirect doubt about climate change and (iii) doubt-mongering did not end after the merger. We now conclude with even greater confidence that ExxonMobil misled the public, delineating three distinct ways in which they have done so.

1. Introduction

In our recent article (Supran and Oreskes, 2017 *Environ. Res. Lett.* **12** 084019 [1]), we assessed whether ExxonMobil has in the past misled the general public about anthropogenic global warming (AGW) (we refer to Exxon Corporation as ‘Exxon’, Mobil Oil Corporation as ‘Mobil’, ExxonMobil Corporation as ‘ExxonMobil Corp’, and generically refer to all three as ‘ExxonMobil’). Presenting an empirical document-by-document textual content analysis of the company’s private and public climate change communications—including peer-reviewed and non-peer-reviewed publications, internal company documents, and paid, editorial-style advertisements (‘advertorials’) in *The New York Times* (NYT)—we concluded that it has.

After our study was published, we became aware of additional relevant ExxonMobil advertorials not included in our original analysis. Here, we present a

document-by-document content analysis of 1448 advertisements, which include these additional materials. Our original finding is reinforced: between 1989–2004, Mobil and ExxonMobil Corp advertorials overwhelmingly expressed doubt about AGW as real and human-caused, serious, and solvable. By including additional advertorials in this expanded analysis, we now conclude with even greater confidence that Exxon, Mobil, and ExxonMobil Corp misled the public.

We also address a critique that ExxonMobil Corp has raised about our original study: that it ‘obscur[ed] the separateness of the two corporations’, Exxon and Mobil, thereby rendering our conclusions invalid [2, 3]. This was never the case: our article’s citations explicitly attributed each individual advertorial to one of Exxon, Mobil, or ExxonMobil Corp; we did not obscure anything. It is the case that to avoid overcomplicating or belaboring the point, our original article focused on how the three companies—Exxon, Mobil,

and ExxonMobil Corp—have collectively misled the public. We considered this approach appropriate, because when Exxon and Mobil merged, ExxonMobil Corp inherited legal and moral responsibility for the parent companies. We reject the implied argument that ExxonMobil Corp is somehow not responsible for the actions of Exxon or Mobil, whatever they may have been. Here, we show ExxonMobil Corp's critique to be incorrect both statistically and at the level of individual documents. We delineate three distinct ways in which the data demonstrate that Exxon, Mobil, and ExxonMobil Corp have all, variously, misled the public about AGW.

2. Method

Previously we demonstrated that between 1989–2004, available advertorials—paid, editorial-style advertisements on the Op-Ed page of the *NYT*—published by Mobil and ExxonMobil Corp overwhelmingly expressed doubt about AGW as real and human-caused, serious, and solvable [1]. In this study, we analyze additional advertorials that came to light after our study was published.

We adopt the same methodology as in our prior study, characterizing each document's manifest content in terms of its (i) topic, (ii) position with respect to AGW, and (iii) position with respect to risks of stranded fossil fuel assets [1]. Results from our original analysis of the 32 Internal memos, 72 Peer-Reviewed articles, and 47 Non-Peer-Reviewed articles made available by ExxonMobil Corp are carried forward (see table 1). As before, our analysis compares these documents with Mobil and ExxonMobil Corp's public outreach in the form of advertorials in the *NYT*.

We previously analyzed 36 AGW-relevant advertorials from a collection of 97 compiled by *PolluterWatch* based on a search of the ProQuest archive [1, 6, 7]. Here, we add to this dataset of 36 by running two additional Boolean ProQuest searches (see section S1, supplementary information for details). In the first, we query for all advertisements in the *NYT* between 1923 and 2018 that refer to 'Mobil' or 'Exxon' or 'ExxonMobil' and to one or more of 13 keywords pertaining to AGW (based on a word frequency analysis of all advertorials included in [1]): 'climate' or 'climate change' or 'greenhouse' or 'global' or 'warming' or 'Kyoto' or 'carbon' or 'CO₂' or 'dioxide' or 'temperature' or 'GHG' or 'Fahrenheit' or 'Celsius'. This relevance sample search yielded 1412 documents [8]. In our second search, we query for all advertisements published in the *NYT* on Thursdays between 1970 and 2018, and that refer to 'climate change' or 'global warming' or 'greenhouse gas' or 'greenhouse gases' or 'greenhouse effect' or 'carbon dioxide' or 'CO₂'. (This search specifically targets Mobil and ExxonMobil Corp's 'every Thursday' (1972–2001) and 'every other Thursday' (2001+)

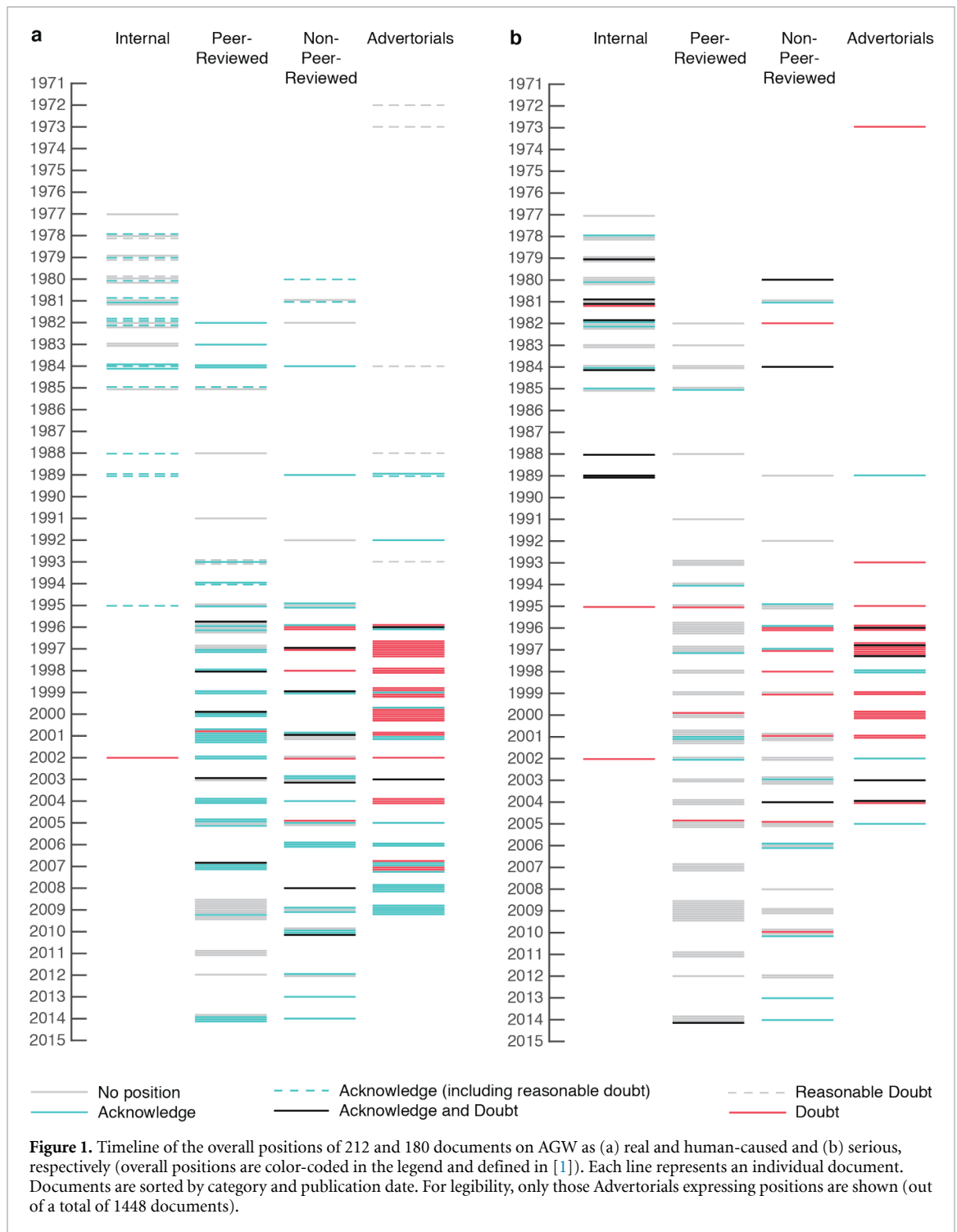
advertorials [9, 10].) This search yielded 138 documents. Combining the above three datasets and removing redundancies yielded a total of 1448 documents spanning 1924–2013 (see table S4, supplementary information). Despite our comprehensive search, additional unidentified advertorials may, of course, exist. We would welcome ExxonMobil Corp making publicly available a complete online database of its—and Mobil's—advertorials in all newspapers (archived versions of the company's website show that in the past, some—but not all—advertorials were listed, albeit misrepresented as 'Op-Eds' [11]).

Eight research assistants conducted an initial, high-level content analysis to filter for relevance the 1412 documents generated by the first ProQuest search. The assistants downloaded and inspected each individual document within assigned publication windows spanning one to ten years. Applying a standardized procedure, they binned each document as either 'irrelevant' or 'not irrelevant' (subcategories of 'relevant', 'generic', and 'ambiguous') to AGW, erring heavily on the side of caution (even most 'not irrelevant' documents do not, in fact, express any positions on AGW). The remainder of the 1448 documents were likewise binned by one of the authors. To verify intercoder reliability, each analyst independently coded a random subset of 100 documents (approximately 7% of the total number of documents; equivalent, on average, to 61% of the number of documents analyzed by each assistant). In sum, this yielded 267 'not irrelevant' advertorials (intercoder reliability: percentage agreement = 92%; Krippendorff's $\alpha = 0.77$; these are conservative lower-bounds owing to Type I errors, the true value is close to unity—for details see section S1, supplementary information). The authors then coded these 267 advertorials according to the content analysis scheme detailed in [1]. (This included occasional reevaluations of codes assigned in our original analysis.)

We have also obtained additional non-peer-reviewed documents not included in our original study, such as company reports, webpages, and speeches. These inform our interpretation of the results of our content analysis. The sources for these additional documents include the Climate Files archive maintained by Climate Investigations Center, ExxonMobil webpages, and digital archives (Wayback Machine) of earlier ExxonMobil webpages [12, 13]. Unlike other document categories, which are bound sets, non-peer-reviewed documents are virtually limitless in potential number and scope (see footnote on p. 2, [1]). Accordingly, while we introduce specific new non-peer-reviewed documents in this paper in order to inform our Discussion, we do not systematically assess their positions using content analysis. Table 1 and figures 1 and 2 reflect only those non-peer-reviewed documents included in our original 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. The internal, peer-reviewed, and non-peer-reviewed documents are those studied in [1]. 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 Corp 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 [4]; ‘Supporting Materials’ are internal documents offered by ExxonMobil Corp [5]; ‘Other’ sources refers to documents discovered independently during our research; ICN = *InsideClimate News*; NYT = *The New York Times*. NYT advertorials were collated from Polluter Watch and ProQuest [6, 7]; an initial relevance sample search yielded 1448 documents, from which 267 ‘not irrelevant’ advertorials were identified for further content analysis. For details on document types, see section S2, supplementary information (available online at <https://stacks.iop.org/ERL/15/119401/nmedia>), [1]. Miscellaneous Opinions include, for example, commentaries, opinion editorials, and speeches.

Category	No.	Dates	Sources										Document types								
			Provided by ExxonMobil Corp										Academic Journal		Conference/Workshop proceeding		Gov. report		Industry White Paper		Misc. opinion (e.g. comment, op-ed, speech)
			‘Peer-reviewed’	‘Additional’	‘Supporting materials’	ICN	NYT	Other	Journal	Workshop	Gov.	report	Book	Paper	Internal doc.	Ad					
Internal documents	32	1977–1995	0	0	22	28	0	1	0	0	0	0	0	0	0	0	32	0	0	0	
Peer-reviewed	72	1982–2014	19	0	0	0	3	53	2	13	4	0	0	0	0	0	0	0	0	0	
Non-peer-reviewed	47	1980–2014	3	29	0	3	12	0	24	5	2	2	0	0	0	0	0	0	0	13	
Advertorials	1448	1924–2013	0	0	0	0	1448	0	0	0	0	0	0	0	0	0	0	0	1448	0	

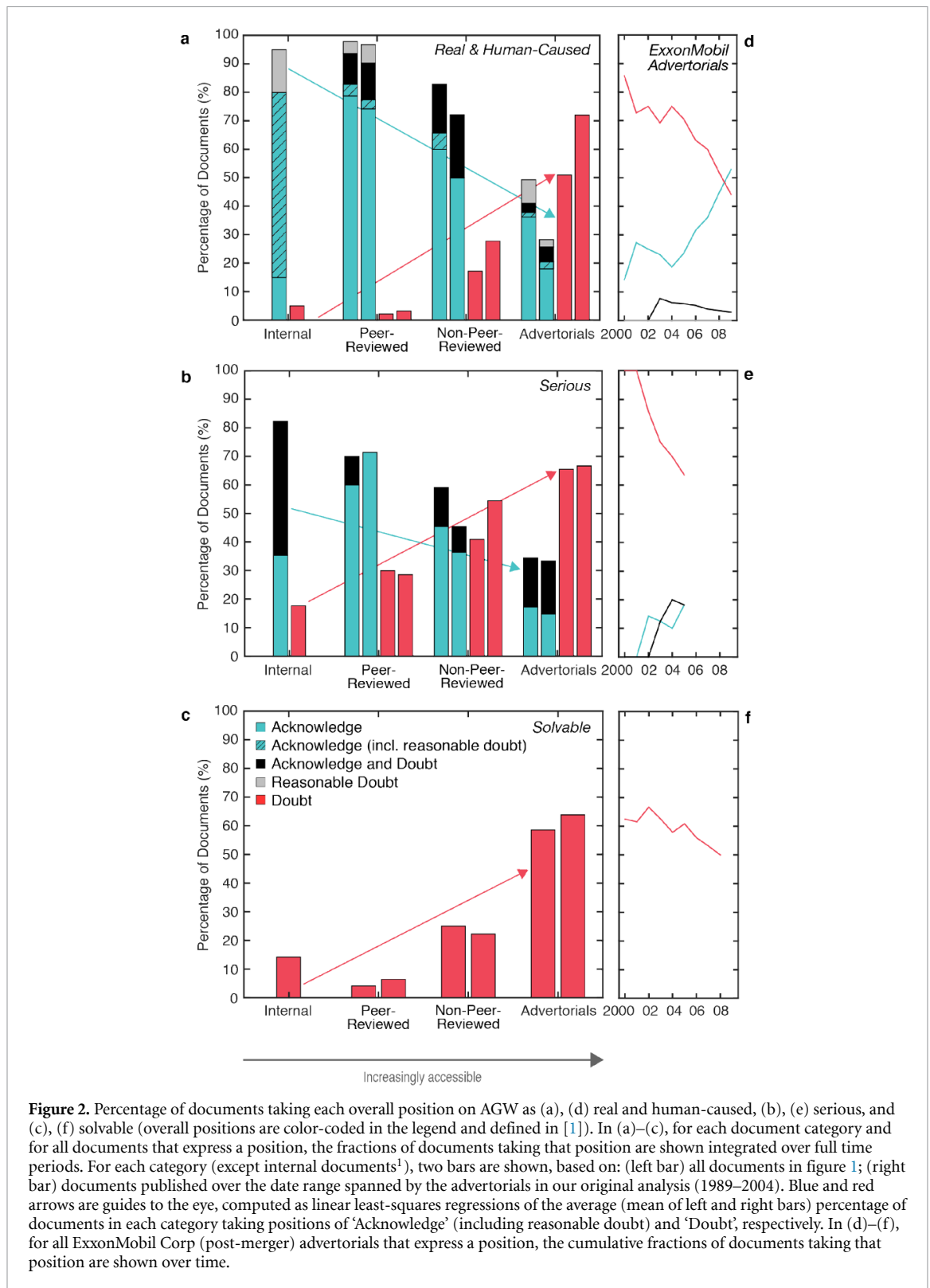


3. Results

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

Figure 1(a) is a timeline of the overall positions of 212 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 (see [1] for definitions): No position (grey); Acknowledge (blue);

Acknowledge and Doubt (black); and Doubt (red). Dashed lines indicate documents that have been filtered for reasonable doubt. ELs for Internal, Peer-Reviewed, and Non-Peer-Reviewed documents are reproduced from our original analysis. ELs are shown for 61 advertorials, spanning 1972–2009, found to express a position (for legibility, the remainder of the 1448 documents with no position are not shown). For each category and for all documents that express a position, figure 2(a) shows the fractions of documents that take that position. For each category (except



internal documents¹), two bars are shown: the left bar of each pair is based on all documents in figure 1; the right bar is based on documents published over

the date range spanned by the advertorials in our original analysis (1989–2004), allowing direct comparison to [1]. In both cases (1972–2014 and 1989–2004), positions on AGW as real and human-caused vary significantly across document categories (Fisher’s exact test, FET: $p = 8.8 \times 10^{-10}$ and $p = 7.0 \times 10^{-9}$, respectively; see section S2, supplementary information, for details and all probability values).

¹As in [1], only one bar is shown for internal documents, based on all internal documents (1977–2002), because only 4 of the 20 internal documents expressing a position fall between 1989–2004.

3.1.1. Peer-reviewed, non-peer-reviewed, and internal documents

For detailed descriptions of the positions of Exxon and ExxonMobil Corp's peer-reviewed, non-peer-reviewed, and internal documents, see [1]. Figures 1(a) and 2(a) show that Exxon and ExxonMobil Corp's peer-reviewed publications overwhelmingly acknowledge AGW as real and human-caused ('Acknowledge'). Over the timespan of all documents (left bars in figure 2(a)¹; see right bars for 1989–2004), of the 65% (47/72) of peer-reviewed documents that express a position, more than four-fifths hold an 'Acknowledge' position (39/47 = 83%). The predominant stance 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). 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. Finally, the bulk of Exxon's internal documents also take the 'Acknowledge' stance. 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%).

3.1.2. Advertorials

In contrast, the predominant stance in Mobil and ExxonMobil Corp advertorials between 1989 and 2004 is 'Doubt', consistent with our original results (e.g. peer-reviewed publications versus advertorials: $p = 2.9 \times 10^{-9}$, FET). Figures 1(a) and 2(a) (right bars) show that of the 8.5% (39/457) of advertorial search results over this period that take a position (including 13 new advertorials uncovered by our ProQuest searches), 72% (28/39) take the position of 'Doubt', with the remainder mostly split between 'Acknowledge' (8/39 = 21%) and 'Acknowledge and Doubt' (2/39 = 5%). Table 2 (top row) provides sample quotations (see section S4, supplementary information, for substantiating quotations for all advertorials). A characteristic example not included in our original dataset is a 2000 ExxonMobil Corp (not Mobil or Exxon) advertorial in the *NYT* and *The Washington Post*, in which the company criticized a US National Assessment report on climate change as putting the 'political cart before a scientific horse' and being based 'on unreliable models' that were 'not yet capable of predicting Earth's global climate' [14, 15]. 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' [16]. Another 2000 ExxonMobil Corp advertorial says that 'climate change may appear as confusing as a maze' [17].

Expanding beyond our original analysis to include 4 and 18 new advertorials published pre-1989

and post-2004, respectively, figures 1(a) and 2(a) (left bars) show that 'Doubt' continues to account for half of all positions (31/61 = 51%), though it loses some ground to the 'Acknowledge' stance (23/61 = 38%). The remaining positions are shared between 'Reasonable Doubt' and 'Acknowledge and Doubt' (5/61 = 8% and 2/61 = 3%, respectively). Examples of 'Doubt' include three ExxonMobil Corp advertorials in 2007, which, despite acknowledging 'the risks of climate change', variously say that 'climate science remains extraordinarily complex', that it is 'evolving', and that 'areas of uncertainty do exist' [18–20]. Of those advertorials expressing 'Acknowledge' from 2005 onwards, 93% (14/15) do so only implicitly (EP3a), almost exclusively by discussing mitigation (such as energy efficiency and technology innovation) rather than climate science. None explicitly say that climate change is real and human-caused.

Accompanying the emergence of implicit acknowledgments is a rhetorical framework focused on 'risk'. 'Risk(s)' of AGW (or of greenhouse gases) becomes ExxonMobil Corp's watchword, appearing at least once in 87% (13/15) of these advertorials (table S4, supplementary information). A characteristic example is a 2007 advertorial entitled 'Saving Energy and Reducing Greenhouse Gas Emissions', which refers to 'steps ExxonMobil is taking to address the risk of climate change' and says that 'industry, consumers and policymakers all have a role to play in addressing the risks of climate change' [21]. A 2008 advertorial discusses lower-carbon fuels and other approaches to 'addressing the risks posed by rising greenhouse gas emissions', but without mentioning AGW [22].

These observations—of implicit acknowledgments and 'risk' rhetoric—are part of a wider trend. Regarding the former: across all advertorials in all years, only two express any form of explicit acknowledgment (EP2). One, a borderline case in 2005, does so only indirectly, by quoting a statement from the Group of Eight (G8) that does not address causation [23]. The other, in 1989, is not in fact an advertorial, but an advertisement in *The New York Times Magazine* that may or may not have actually included Exxon among its industry sponsors [24]. All other acknowledgments are implicit: they avoid directly addressing climate science and the issue of human causation, instead discussing emissions reductions strategies. Figure S1, supplementary information, shows that from the late 1990s onwards, advertorials focused on mitigation rapidly outnumbered those focused on methods and climate science—cumulatively, by more than three-to-one.

We shall address the wider trend concerning 'risk' rhetoric in a forthcoming study. See table 3, however, for examples of the pervasiveness of 'risk' language in ExxonMobil Corp's public communications about AGW.

Table 2. Example quotations (coding units) from Mobil/ExxonMobil Corp advertorials expressing (left) acknowledgment and (right) doubt that AGW is (top row) real and human-caused, (middle row) serious, and (bottom row) solvable. Quotations are sourced only from advertorials not included in [1]. For each position, two examples are given: the first typifies a relatively ‘strong’ quotation, the second a relatively ‘mild’ one (except AGW as serious, for which only one new advertorial expresses acknowledgment; and except for AGW as solvable, for which only ‘Doubt’ is coded). Substantiating quotations for all advertorials are provided in section S4, supplementary information.

	Acknowledge		Doubt	
AGW as real & human-caused (EP1,2,3)	2007	Title: ‘Saving Energy and Reducing Greenhouse Gas Emissions’. ‘Two weeks ago, we described some of the steps ExxonMobil is taking to address the risk of climate change. These included working to improve energy efficiency and fuel economy, and groundbreaking research into low-emissions technologies. This week, we focus on consumers...industry, consumers and policy-makers all have a role to play in addressing the risks of climate change’ [21].	2000	Title: ‘Political cart before a scientific horse’. ‘The Clinton administration has released a draft overview of the purported potential effects of climate change on specific U.S. geographic regions and economic sectors...But as climate scientists will tell you, we currently have neither the knowledge nor the tools to [produce an accurate assessment]...Climate models are evolving research tools but are not yet capable of predicting Earth’s global climate and are currently unsuitable for making national or regional assessments’. Advertorial cites ‘key scientific uncertainties’ and quotes Freeman J. Dyson, calling climate models ‘unreliable’. ‘Most of the underlying reports and analyses are not yet available for scientific peer review...’ [this was untrue—see [16]] [14].
	2008	‘To meet this [higher future global energy] demand, while addressing the risks posed by rising greenhouse gas emissions, we will need to call upon a broad mix of energy sources’ [22].	2007	‘Climate remains an extraordinarily complex area of scientific study. But the risks to society and ecosystems from climate change could prove to be significant—so despite the areas of uncertainty that do exist, it is prudent to develop and implement strategies that address the risks’ [20].

(continued)

Table 2. (Continued).

	Acknowledge	Doubt
AGW as serious (IP1,3)	<p>2005 “Climate change is a serious and long-term challenge that has the potential to affect every part of the globe.” These quotes— with which we agree entirely— were among those endorsed by government leaders at the recent G8 meeting in Gleneagles, Scotland’ [23].</p>	<p>1993 Title: ‘Apocalypse no’. ‘For the first half of 1992, America was inundated by the media with dire predictions of global warming catastrophes...Unfortunately, the media hype proclaiming that the sky was falling did not properly portray the consensus of the scientific community. After the Earth Summit, there was a noticeable lack of evidence of the sky actually falling and subsequent colder than normal temperatures across the country cooled the warming hysteria as well’. ‘If nothing else, [The Heidelberg Appeal’s] message is illustrative of what’s wrong with so much of the global warming rhetoric. The lack of scientific data’. Quoting Robert C. Balling: “there is a large amount of empirical evidence suggesting that the apocalyptic vision is in error and that the highly touted greenhouse disaster is most improbable?” Quoting S. Fred Singer: “the net impact [of a modest warming] may well be beneficial.” ‘All of which would seem to suggest that the jury’s still out on whether drastic steps to curb CO₂ emissions are needed’ [25].</p> <p>1996 ‘Such speed [of international climate action] may not be needed or even desirable given what we know and do not know about the economic and environmental impact of what climate change might produce’ [26].</p>
AGW as solvable (SP1)		<p>1996 UN-sponsored climate action ‘is likely to cause severe economic dislocations...If developed nations act <i>alone</i> to reduce emissions, the staggering cost imposed on energy-intensive industries will drive nations to export much of their industrial base to countries with less stringent controls. World economic health will suffer as nations are forced to switch from fossil fuels, saddled with large carbon taxes and driven to prematurely scrap many factories and machinery. The dislocations will be even more severe if the solutions are not implemented globally...Jobs and livelihoods are at stake [in deciding on climate policy]’ [26].</p> <p>2007 ‘Businesses, governments and NGOs are faced with a daunting task: selecting policies that balance economic growth and human development with the risks of climate change’ [18, 19].</p>

3.2. Impact Levels (ILs)—AGW as serious

Figure 1(b) is a timeline of the overall positions of 180 documents on AGW as serious. ILs for Internal, Peer-Reviewed, and Non-Peer-Reviewed documents are reproduced from [1]. ILs are shown for 29 Advertorials, spanning 1973–2005, found to express a position. For each category and for all documents that take a position, figure 2(b) shows the fractions of documents that take that position. For both spans of documents shown in figure 2(b) (left bar: 1973–2014; right bar: 1989–2004), positions on AGW as serious vary significantly across document categories at $p < 0.1$ (FET: (1973–2014) $p = 0.066$; (1989–2004) $p = 0.061$).

3.2.1. Peer-reviewed, non-peer-reviewed, and internal documents

For detailed descriptions of the positions of Exxon and ExxonMobil Corp's peer-reviewed, non-peer-reviewed, and internal documents, see [1]. In summary, figures 1(b) and 2(b) show that over the timespan of all documents (left bars in figure 2(b)¹; see right bars for 1989–2004), of the 10 peer-reviewed publications that discuss the potential impacts of AGW, 60% (6/10) take a position of 'Acknowledge', 30% (3/10) of 'Doubt', and 10% (1/10) of 'Acknowledge and Doubt'. Non-peer-reviewed documents offer a mix of positions. Among the 47% (22/47) that take a position, 45% (10/22) 'Acknowledge', 41% (9/22) 'Doubt', and 14% (3/22) 'Acknowledge and Doubt'. Finally, internal documents also 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'.

3.2.2. Advertorials

Mobil and ExxonMobil Corp's advertorials overwhelmingly take the position of 'Doubt', consistent with our original findings (e.g. peer-reviewed publications versus advertorials, FET: (1973–2014) $p = 0.043$; (1989–2004) $P = 0.014$). Figures 1(b) and 2(b) (right bars) show that over the period 1989–2004 covered in our original analysis, of the 5.9% (27/457) of advertorial search results that take a position (including six new advertorials from our ProQuest searches), 66.5% (18/27) express 'Doubt', with the remainder split between 'Acknowledge' and 'Acknowledge and Doubt' (4/27 = 15% and 5/27 = 18.5%, respectively). A characteristic example (table 2, middle row) not included in our original dataset is a 1996 Mobil advertorial saying that 'such speed [of international climate action] may not be needed or even desirable given what we know and do not know about the economic and environmental impact of what climate change might produce' [26]. The 2000 ExxonMobil Corp advertorial discussed earlier claims that the US National Assessment 'report's language and logic appear designed to

emphasize selective results to convince people that climate change will adversely impact their lives'—implying that it will not [14, 15]. A third example is a 1993 Mobil advertorial entitled 'Apocalypse No' [25], which claims that 'dire predictions of global warming catastrophes' in 1992 were 'media hype' that 'did not properly portray the consensus of the scientific community'. It goes on to argue that 'what's wrong with so much of the global warming rhetoric' is 'the lack of solid scientific data', and alleges 'a noticeable lack of evidence of the sky actually falling' and 'colder than normal temperatures' in the US. The advertorial quotes prominent climate contrarian Robert C. Balling, who argues 'that the apocalyptic vision is in error and that the highly touted greenhouse disaster is most improbable'. The advertorial also quotes physicist S Fred Singer, well known at the time for challenging the scientific evidence of stratospheric ozone depletion, claiming that: 'the net impact [of a modest warming] may well be beneficial' [27].

Expanding beyond our original analysis to include all years has little effect on the overall result: 'Doubt' continues to dominate (19/29 = 66%), while 'Acknowledge' and 'Acknowledge and Doubt' make up the difference (5/29 = 17% apiece). Post-2004, advertorials are virtually silent about the seriousness of AGW (beyond generic 'risk' statements—see [1]). In other public communications, however, this doubt has continued (a few examples are given in table 3—see ExxonMobil Corp statements from ~2008 onwards).

3.3. Solvable Levels (SLs)—AGW as solvable

Positions on AGW as solvable vary significantly across document categories (FET: (all years with positions, 1981–2008) $p = 9.0 \times 10^{-11}$; (1989–2004) $p = 6.9 \times 10^{-10}$). Expressed as a fraction of the total number of documents per category communicating any positions on AGW (real and human-caused, serious, or solvable), figure 2(c) (left bars¹) shows that over the timespan of all documents, only 4% (2/48) of peer-reviewed papers express 'Doubt' that AGW is solvable. Internal and non-peer-reviewed materials also express relatively low levels of doubt: 14% (3/21) and 25% (9/36), respectively. In contrast, 58% (45/77) of advertorials do so (e.g. peer-reviewed publications versus advertorials: $p = 9.1 \times 10^{-11}$, FET). Similarly, figure 2(c) (right bars) shows that over the period 1989–2004 covered in our original analysis, levels of 'Doubt' are: 6% (2/31) of peer-reviewed papers, 22% (4/18) of non-peer-reviewed documents, and 64% (37/51) of advertorials (e.g. peer-reviewed publications versus advertorials: $p = 2.2 \times 10^{-9}$, FET).

A characteristic example of doubt that AGW can be effectively addressed (table 2, bottom row) is a 2000 ExxonMobil Corp advertorial (not included in our original dataset) that says the Kyoto Protocol to the United Nations Framework Convention on

Table 3. Examples of public doubt about AGW either directly communicated or indirectly funded by ExxonMobil Corp following the merger of Exxon and Mobil. Quotations are sourced from documents not included in our content analysis, such as company reports, speeches, newspaper accounts, and archived websites. Although we do not formally code the positions of these statements on AGW, and the relative ‘strengths’ of doubt vary from statement to statement, ExxonMobil Corp’s direct representations through 2007/8 appear to express doubt about AGW as real and human-caused. Through to the present day, the company continues to itself question the ‘competency’ of climate models and the role of humans as the ‘principal drivers of climate change’, yet emphasis also shifts to promoting doubt about AGW as serious and solvable (as indicated, most statements also include ‘risk’ rhetoric). Examples are also given of third-party individuals and organizations funded by ExxonMobil Corp that have communicated doubt about AGW as real and human-caused, serious, or solvable in the recent past and/or present.

Year	Publication	Quotation
2000	Company report (preface by CEO Lee Raymond) [106]	Raymond: ‘[W]e do not now have a sufficient scientific understanding of climate change to make reasonable predictions and/or justify drastic measures...the science of climate change is uncertain...’ ‘[N]atural period of warming’ (ice ages), ‘solar activity’, ‘[v]olcanic eruptions, El Nino’: ‘With all this natural climate ‘noise’ and the complexities of measurement, science is not now able to confirm that fossil fuel use has led to any significant global warming...Currently, there does not appear to be a consensus among scientists about the effect of fossil fuel use on climate’. Risk rhetoric: ‘it may pose a legitimate long-term risk...’.
2001	‘Climate talking points’ in press release [44]	‘Misinformation exists over the role and membership of IPCC: it is not a research organization and its members are not scientists... scientists work together only in the small teams that draft individual chapters... [IPCC’s climate science models] have...fundamental gaps in basic understanding...’. Regarding the ‘Hockey Stick’ graph showing global warming: ‘The error bars are huge, yet some prefer to ignore them’. Risk rhetoric: ‘long-term risk(s)’.
2001	Lee Raymond, speech [105]	‘We need good, and better, climate science...if we cannot forecast the weather a week from now, I would be suspect of our ability to forecast the climate 100 years from today’. Risk rhetoric: ‘risks’.
2001	Press release [106]	‘[T]here is no consensus about long-term climate trends and what causes them...during the 1970’s [sic], people were concerned about global cooling’. Risk rhetoric: ‘long-term risks’.
2002	Lee Raymond, speech [107]	‘We in ExxonMobil do not believe that the science required to establish this linkage between fossil fuels and warming has been demonstrated—and many scientists agree... [T]his is because of incomplete data and methodology and the overarching role of natural variability’. Risk rhetoric: ‘risk’.
2004	Company report [108]	‘ExxonMobil recognizes that although scientific evidence remains inconclusive, the potential impacts of greenhouse gas emissions...may prove to be significant...Climate: Infinitely more complex than weather... [T]he cause of this [global warming] trend and whether it is abnormal remain in dispute... [T]he geological record...shows considerable variation’. Cites numerous non-human factors influencing climate. Risk rhetoric: ‘risks’.
2005	Academic article funded by ExxonMobil (also Charles G Koch Charitable Foundation and American Petroleum Institute) [109]	‘[T]he hypothesis of a CO ₂ -dominated warming of the Arctic is not likely consistent with the large decadal-and-multidecadal warming and cooling signals contained in the Arctic-wide SAT record’.
2005	Lee Raymond, television interview [96]	‘There is a natural variability that has nothing to do with man...It has to do with sun spots...with the wobble of the Earth... [T]he science is not there to make that determination [as to whether global warming is human-caused]... [T]here are a lot of other scientists that do not agree with [the National Academy and IPCC]... [T]he data is not compelling’.
2006–2007	ExxonMobil website & 2005 Corporate Citizenship Report [110]	‘Climate science is complex...the extent to which recent temperature changes can be attributed to greenhouse gas increases remains uncertain... [G]aps in the scientific basis for theoretical climate models and the interplay of significant natural variability make it very difficult to determine objectively the extent to which recent climate changes might be the result of human actions’. Risk rhetoric: ‘risk(s)’.
2007	Academic (non-peer-reviewed) article funded by ExxonMobil (also Charles G Koch Charitable Foundation and American Petroleum Institute) [111]	‘[I]t is highly premature to argue for the extinction of polar bear [sic] across the circumpolar Arctic within this century...It is certainly premature, if not impossible, to tie recent regional climatic variability in this part of central Canada to anthropogenic greenhouse gases and, further, to extrapolate species-level conditions on this basis... [T]here is no ground for raising public alarm about any imminent extinction of Arctic polar bears’.

(continued)

Table 3. (Continue).

Year	Publication	Quotation
2008	CEO Rex Tillerson, interview [112]	'...to not have a debate on [AGW] is irresponsible... To suggest that we know everything we need to know about these issues is irresponsible... Anybody that tells you that they got this figured out is not being truthful. There are too many complexities around climate science for anybody to fully understand all of the causes and effects and consequences of what you may chose to do to attempt to affect that. We have to let scientists to [sic] continue their investigative work, unencumbered by political influences'.
2010	Rex Tillerson, Congressional testimony [113]	'[T]here is no question climate is changing, that one of the contributors to climate change are greenhouse gases that are a result of industrial activities—and there are many greenhouse gases besides CO ₂ ... [T]he real challenge I think for all of us is understanding to what extent and therefore what can you do about it... [L]et us continue to support the scientific investigation... It is extremely complicated... So, yes, we acknowledge that it is a contributing factor. Where I think we have differences [is that] we understand the difficulties of modeling the science... [T]here is not a model available today that is competent... So we say keep studying it'. Risk rhetoric: 'risk management'.
2012	Rex Tillerson, speech [114]	'[T]he competencies of the [climate] models are not particularly good... We cannot model aerosols; we cannot model clouds, which are big, big factors in how the CO ₂ concentrations in the atmosphere affect temperatures... [O]ur ability to predict, with any accuracy, what the future's going to be is really pretty limited... I am not disputing that increasing CO ₂ emissions in the atmosphere is going to have an impact. It will have a warming impact. The—how large it is is [sic] what is very hard for anyone to predict. And depending on how large it is, then projects how dire the consequences are'.
2013	Rex Tillerson, television interview [115]	'[T]he facts remain there are uncertainties around the climate, climate change, why it is changing, what the principal drivers of climate change are. And I think the issue that I think is unfortunate in the public discourse is that the loudest voices are what I call the absolutist, the people who are absolutely certain that it is entirely man-made and you can attribute all of the climate change to nothing but man-made burning of fossil fuels... [T]here are other elements of the climate system that may obviate this one single variable that we are concentrating on because we are concentrating on a single variable in a climate system that has more than 30 variables. We are only working on one. And so that's that uncertainty issue...'. Risk rhetoric: 'risk(s)', 'serious risks', 'managing risks'.
2013	Rex Tillerson, speech [116]	'If you examine the temperature record of the last decade, it really had not changed... Our ability to project with any degree of certainty the future is continuing to be very limited... [O]ur examination about the models are [sic] that they are not competent'. Risk rhetoric: 'risk'.
2014	ExxonMobil affiliate, Syncrude [117]	Syncrude submits that the production and consumption of petroleum fuels is not dangerous and does not pose a risk to human health or safety'.
2015	Senator Jim Inhofe (R-OK), funded by ExxonMobil [118]	'[W]e keep hearing that 2014 has been the warmest year on record. I ask the Chair, 'You know what this is?' It's a snowball, and that's from just outside here, so it's very, very cold out'.
2015	Rex Tillerson, speech [119]	'We do not really know what the climate effects of 600 ppm versus 450 ppm will be because the models simply are not that good'. Risk rhetoric: 'risk management'.
2017	Rex Tillerson, Congressional testimony [120, 121]	'I understand these [greenhouse] gases [due to 'combustion of fossil fuels'] to be a factor in rising temperature, but I do not believe the scientific consensus supports their characterization as the 'key' factor'. Risk rhetoric: 'risk'.
1992-2018	American Legislative Exchange Council, funded by ExxonMobil [122–124]	'Global Climate Change is Inevitable. Climate change is a historical phenomenon and the debate will continue on the significance of natural and anthropogenic contributions'. (2020)
2002-present	National Black Chamber of Commerce, funded by ExxonMobil [125–127]	'There is no sound science to support the claims of Global Warming'. (2020)

Climate Change involved ‘highly unrealistic carbon reduction goals’ that were ‘not possible’ for the US to meet [28]. ‘Ambitious public policies and international treaties that assume very rapid change in total energy use are simply unrealistic’ and ‘attempts to mandate such change are fraught with risk’. Another ExxonMobil Corp advertorial, which appeared twice in 2007, says that ‘businesses, governments and NGOs are faced with a daunting task: selecting policies that balance economic growth and human development with the risks of climate change’ [18, 19]. These advertorials echo two of the prominent themes of ‘Doubt’ identified in our original analysis: (i) an alleged dichotomy between climate mitigation and poverty reduction, and (ii) the allegedly severe adverse economic impacts of mitigation [1]. A third example is a 1996 Mobil advertorial that states: ‘[UN-sponsored climate action] is likely to cause severe economic dislocations at a time when many nations are striving for growth and jobs...World economic health will suffer as nations are forced to switch from fossil fuels, saddled with large carbon taxes and driven to prematurely scrap many factories and machinery...Jobs and livelihoods are at stake’ [26].

As might be expected, the content and tone of advertorials change with time. As the scientific evidence of AGW strengthened in the early 2000s, advertorials began to include discussion of options for greenhouse gas emissions reductions, such as investment in energy efficiency and technology research and development. This is the context in which the third ‘Doubt’ argument we identified in our original study appears: insisting on the limitations of renewable energy [1]. A 2001 Exxon-Mobil Corp advertorial expresses a characteristic sentiment: ‘Though promising, renewable energy’s potential should be tempered with realism’ [29]. The advertorial points out that wind power ‘generally enjoys tax subsidies’, yet says nothing about the much larger subsidies that fossil fuels receive [30–32]. In various forms, the advertorials reinforce the presumed inevitability of continued fossil fuel dominance [33–36].

3.4. Stranded fossil fuel assets

As discussed in [1], 24 of the analyzed documents allude to the concept of stranded fossil fuel assets. Our updated analysis finds that, as before, no advertorials address the issue. Therefore, the contrast across document categories remains clear and statistically significant: the threat of stranded assets is recognized in internal and academic documents, but never mentioned in advertorials (FET: (all years) $p = 3.3 \times 10^{-7}$; (1989–2004) $p = 3.2 \times 10^{-6}$).

3.5. Summary of results

Our ProQuest searches described herein add 18 advertorials expressing positions on AGW (real and human-caused, serious, or solvable) to those included

in our original analysis spanning 1989–2004, and 26 outside of these years (these new documents are indicated by yellow highlights in table S4, supplementary information).

An updated analysis of the period 1989–2004 continues to yield statistically significant results, and our conclusions therefore remain unchanged: between 1989–2004, Mobil and ExxonMobil Corp advertorials overwhelmingly expressed doubt about AGW as real and human-caused, serious, and solvable. Indeed, having augmented our archive of advertorials, and with our prior document codings undisputed by ExxonMobil Corp’s critiques, our original conclusions are now strengthened [2, 3].

Expanding beyond the timeframe of our original analysis negligibly affects the overall positions of advertorials on AGW as serious and solvable: Over all years with advertorial positions (1973–2005 and 1988–2008, respectively), ‘Doubt’ remains the overwhelming position in both respects (sections 3.2.2 and 3.3). The predominant stance over all years on AGW as real and human-caused also remains ‘Doubt’ (section 3.1.2). From 2005–09 this is reduced, with the positions of advertorials transitioning from mostly ‘Doubt’ (1989–2004) to mostly ‘Acknowledge’, punctuated by doubt in 2007 (figure 1(a)).

Most of these recent ‘Acknowledgments’ are ambiguous. As described in section 3.1.2, the vast majority (93%) are implicit: in no case does Exxon-Mobil Corp state that climate change is real and human-caused. Nor do they acknowledge a change in their position. In this sense, the acknowledgments are asymmetric compared to the doubt promoted in earlier advertorials. Earlier advertorials *explicitly* challenged climate science; later ones merely sidestepped it, citing undefined ‘risk(s)’ of climate change (87% of post-2004 advertorials) and discussing options for emissions reductions without stating why they are necessary.

4. Discussion

Our results imply at least three ways in which Exxon, Mobil, and ExxonMobil Corp have, variously, misled the public about AGW. Sections 4.1–4.3 address each of these in turn.

4.1. Exxon and ExxonMobil Corp misled with discrepant communications

The first way the public was misled derives from the results of our content analysis and relies on a line of reasoning presented in our original paper: comparison across company document categories.

Figure 2(d) shows that from 2000 through 2004 (after the Exxon-Mobil merger), the overwhelming position of ExxonMobil Corp advertorials on AGW as real and human-caused continued to be ‘Doubt’ (12/16 = 75%). The discrepancy between this doubt and the predominant acknowledgment in Exxon

and ExxonMobil Corp peer-reviewed, non-peer-reviewed, and internal documents shown in figure 1(a) is statistically significant (FET: $p = 8.5 \times 10^{-8}$, $p = 0.0079$, and $p = 1.6 \times 10^{-5}$, respectively, for all peer-reviewed, non-peer-reviewed, and internal documents through 2004). From a statistical standpoint it is essentially certain that whereas Exxon and ExxonMobil Corp's private and academic documents predominantly acknowledge that climate change is real and human-caused, ExxonMobil Corp's advertorials disproportionately—and overwhelmingly—promote doubt on the same matter. This unambiguously reaffirms our original conclusion.

The contrast across document categories—that is, evidence of misleading communications—is also clear when analyzed at a year-to-year scale (figure 1(a)). During the early 2000s, ExxonMobil Corp's peer-reviewed publications and advertorials in the same years contradict one another. For instance, in 2004, one peer-reviewed ExxonMobil Corp publication refers to 'the fraction of anthropogenic CO₂ emissions that remains in the atmosphere, and contributes to the radiative forcing of climate'; another presents 'cumulative CO₂ emissions' for a '550 ppm stabilization trajectory'; and a third discusses 'CO₂ disposal as an option to mitigate climate change from an enhanced greenhouse effect' [37–39]. Yet, that same year, one ExxonMobil Corp advertorial stressed the alleged 'debate over climate change' and fostered uncertainty that AGW had been observed, saying 'last year's record summer heat in Europe does not confirm a warming world' (climate attribution assessments have since disproved this claim [40]). They insisted that 'in the face of natural variability and complexity, the consequences of change in any single factor, for example greenhouse gases, cannot readily be isolated and prediction becomes difficult... scientific uncertainties continue to limit our ability to make objective, quantitative determinations regarding the human role in recent climate change or the degree and consequences of future change' [41]. Another advertorial the same year emphasized the 'gaps and uncertainties that limit our current ability to know the extent to which humans are affecting climate and to predict future changes caused by both human and natural forces' [42].

Given these discrepancies it is clear that ExxonMobil Corp misled the public over this period. The historical record categorically refutes ExxonMobil Corp's recent claims that only Mobil was responsible for misleading advertorials (and for other misleading communications, as we discuss below). Misleading advertorials did not cease when Exxon and Mobil merged.

Figures 2(e) and (f) show that across all ExxonMobil Corp advertorials with positions on AGW as serious and solvable, respectively, levels of 'Doubt' outweigh those in peer-reviewed, non-peer-reviewed, and internal documents (Serious, FET: $p = 0.10$, $p =$

0.87, and $p = 0.093$, respectively; Solvable, FET: $p = 6.0 \times 10^{-6}$, $p = 0.063$, and $p = 0.0027$, respectively). These discrepancies again demonstrate that ExxonMobil Corp misled the public.

Additionally, peer-reviewed, non-peer-reviewed, and internal documents from Exxon and ExxonMobil Corp acknowledge the risks of stranded assets (24 times), whereas ExxonMobil Corp's advertorials do not ($p = 3.3 \times 10^{-7}$, FET). This imbalance has not been disputed by ExxonMobil Corp in its critiques of our original study [2, 3].

The significance of these discrepancies is compounded by the imbalance in the physical and intellectual accessibility of advertorials versus other document categories. As evidenced in our original study, ExxonMobil contributed to scientific articles with likely average readerships of tens to hundreds, yet raised doubts about that science in newspapers potentially read by millions of people [1].

Non-peer-reviewed Exxon and ExxonMobil Corp documents also communicate greater doubt about AGW as real and human-caused and solvable than peer-reviewed Exxon and ExxonMobil Corp publications (and, with respect to real and human-caused positions, than Exxon and ExxonMobil Corp internal documents) (figures 1(a) and (c)). Although this discrepancy is smaller, it is statistically significant at or below $p < 0.1$ (FET: (real and human-caused) $p = 0.044$ for peer-reviewed publications and $p = 0.077$ for internal memos; (solvable) $p = 0.0076$), suggesting that Exxon and ExxonMobil Corp's non-peer-reviewed communications, which tended to be more orientated towards non-scientific audiences (such as industry groups and journalists) than peer-reviewed papers, were sometimes misleading.

The non-peer-reviewed documents demonstrate that the doubt ExxonMobil Corp expressed in advertorials post-merger was not an unintentional or isolated incident: it was part of the company's broader public communications effort. As noted in our original paper, there are countless non-peer-reviewed materials beyond those included in our corpus [1]. Table 3 lists just a few examples, among them 'climate talking points' that ExxonMobil Corp distributed to reporters in 2001 as part of a press release specifically promoting their publication of two advertorials ('major ads') in the *Los Angeles Times*, *NYT*, *The Wall Street Journal*, and *The Washington Post* [43]. In step with the advertorials, the talking points question the scientific authority of the Intergovernmental Panel on Climate Change (IPCC) and the validity of the 'Hockey Stick' graph showing global warming, which was a centerpiece of the 2001 IPCC report [44].

4.2. Exxon, Mobil, and ExxonMobil Corp misled with misinforming advertorials and non-peer-reviewed publications

The second way the public was misled also derives from the results of our content analysis and relies

on a line of reasoning presented in our original paper: comparison of public company communications against available scientific information.

ExxonMobil Corp has not disputed any of our original document codings, including those identifying numerous expressions of doubt—some, factual misrepresentations—about AGW (notably in Mobil and ExxonMobil Corp advertorials and Exxon and ExxonMobil Corp non-peer-reviewed publications) [2, 3]. Using as proxies for mainstream climate science both the conclusions of the IPCC (our analysis filters for ‘reasonable’ doubt—see [1]) and the science of Exxon and ExxonMobil Corp itself (ExxonMobil Corp says its ‘researchers recognized the developing nature of climate science at the time...[and] mirrored global understanding’), it is evident that Exxon, Mobil, and ExxonMobil Corp’s public communications were inconsistent with available scientific information and therefore misled the public [45, 46].

4.2.1. What did Mobil know?

ExxonMobil Corp’s critiques of our original study imply that Mobil was oblivious to the insights and warnings of mainstream climate science, even as it ran advertorials attacking that science [2]. Yet a 1997 Mobil advertorial suggests otherwise: ‘We continue to sponsor research at universities...At Columbia’s Lamont-Doherty Geophysical Observatory, we supported work on the role that oceans play in the climate system’ [47].

Additional documents not included in our original analysis confirm that Mobil, like Exxon, had direct access to the insights of mainstream climate science [48–51]. For example, as a 1997 report by Mobil’s Anthony R. Corso summarized, ‘Over the past five years we have funded scientific and economic studies at The Massachusetts Institute of Technology, the Lamont-Dougherty [*sic*²] Geophysical Observatory of Columbia University, the Harvard-Smithsonian Astrological [*sic*] Observatory, and the Australian Bureau of Agricultural and Resource Economics’. [48] Mobil was ‘[f]unding [this] research to increase the understanding of the science and economics of global climate change’.

According to a newly discovered internal budget proposal, ‘1994 Mobil Foundation Grant Recommendations’, Mobil’s funding at Columbia University included \$25 000 per year in 1991 and 1992 and would continue at the same rate in 1993 and 1994 [49]. Mobil described the university’s Lamont-Doherty laboratory as ‘a world-wide leader in earth and atmospheric studies’ and said the purpose of the grant was to ‘develop an improved computer model [that] will become part of the larger models predicting the impact of increased greenhouse

gas emissions on global climate’. ‘Ultimately’, they noted, ‘these models will be the basis for regulatory action’. ‘Benefits to Mobil Foundation’ included ‘[t]echnical information and understanding...key to Mobil’s ability to participate in the debate on [potentially imminent greenhouse gas] regulations...Mobil scientists involved in the global warming issue can gain first hand understanding of the role of the oceans in global warming and develop personal relationships with some of the key experts...[P]articipating at this level is far more valuable to Mobil than merely reading papers...’.

In other words, Mobil had scientists studying AGW and learning from some of the same groups of independent climate experts as Exxon scientists. (For example, from the late 1970s through the mid-1980s, Exxon spent tens of thousands of dollars funding a ‘cooperative program with Lamont-Doherty’ in which scientists at Exxon and Columbia University collaboratively co-authored AGW project proposals and conducted AGW research [52–59]. ExxonMobil Corp has continued to fund the Lamont-Doherty Earth Observatory throughout most of the 2000s to present [60–71].) In turn, those Exxon scientists overwhelmingly acknowledged AGW as real and human-caused. Mobil’s access to these same mainstream scientific resources preceded and paralleled its publication of advertorials attacking climate science and its implications, further demonstrating that Mobil knowingly misled the public.

Mobil was also an active member of the American Petroleum Institute (API), and numerous documents record API’s early awareness of the potential AGW dangers of its products. These include API-commissioned research on carbon dioxide at the California Institute of Technology in 1955; an in-person warning to API by physicist Edward Teller in 1959; API monitoring of warnings about AGW by President Johnson’s Science Advisory Committee in 1965; and API-commissioned research on AGW at Stanford Research Institute in 1968 and 1969 [72–75].

4.3. Exxon and ExxonMobil Corp misled with additional direct and indirect climate denial

The third way the public was misled relies on an additional line of reasoning that was not explicitly discussed in our original paper: comparison of the results of our content analysis against an extensive literature of scholarly research and investigative journalism that has chronicled the company’s history of directly and indirectly perpetuating climate science misinformation.

ExxonMobil Corp has not disputed our document codings, which reveal overwhelming acknowledgement by both Exxon and ExxonMobil Corp scientists that AGW is real and human-caused [2, 3]. At the same time, it is well-documented (based on documents beyond those included in our analysis, as well as on some non-peer-reviewed documents

²Correct spelling is Lamont-Doherty.

included herein) that (i) from at least the 1990s until at least 2015 (and arguably to this day), Exxon and ExxonMobil Corp have sometimes publicly promoted doubt about climate science through direct company communications; and that (ii) from at least the late 1980s through to the present, Exxon and ExxonMobil Corp have funded groups and individuals and participated in organizations that cast doubt in public on climate science [27, 76–103] (table 3 provides a few examples). To our knowledge, ExxonMobil has never disputed its history of direct and indirect climate denial. Likewise, Exxon and ExxonMobil Corp have a track record of directly and indirectly promoting public doubts about AGW as serious and solvable that are inconsistent with the views of company scientists chronicled by our analysis (again, see table 3 for examples).

This comparison—between what ExxonMobil knew and its broader history of climate denial and delay—is an inherent, central line of reasoning in many journalistic and legal investigations of the company. It highlights an important point: Our work does not stand in isolation. At the onset of our study, substantial evidence already existed to suggest that ExxonMobil had misled the public on a variety of aspects of AGW and in a variety of ways [27, 77–82]. The purpose of our study was to bring to bear an additional, complementary empirical methodology to test the hypothesis that ExxonMobil misled the public. Our results show this to be the case.

5. Conclusion

We have updated our original analysis to include additional Mobil and ExxonMobil Corp advertorials in the *NYT*, and have also introduced new documents never previously analyzed in the peer-reviewed literature. Among other things, we have shown that misleading communications, direct and indirect, emanated from both Exxon and Mobil before their 1999 merger, and continued thereafter. We have also introduced new evidence that Mobil was aware of developments in mainstream climate science, even as they took out advertorials that challenged it. We now conclude with even greater confidence that Exxon, Mobil, and ExxonMobil Corp misled the public about climate change.

The history of ExxonMobil's communications about AGW is consistent with what scholars have labeled merchandising doubt, manufacturing doubt, or doubt-mongering [27, 128–135]. A party whose interests are threatened by scientific findings may seek to protect those interests by casting doubt on the science: 'emphasiz[ing] the uncertainty', as a 1988 Exxon strategy memo put it, focusing on 'debate', and suggesting that remedies are unavailable, unrealistic, too expensive, or otherwise undesirable [136]. Often these claims are not made outright, but are insinuations, which are harder to refute. They may also

attack scientists, suggesting they are unreliable or biased. Many of these strategies are evident in ExxonMobil's communications, as well as in their public and private critiques of our work that we have here addressed.

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Data availability statement

The data that support the findings of this study are openly available.

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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’	<i>ICN</i>	<i>NYT</i>									<i>Other</i>
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.

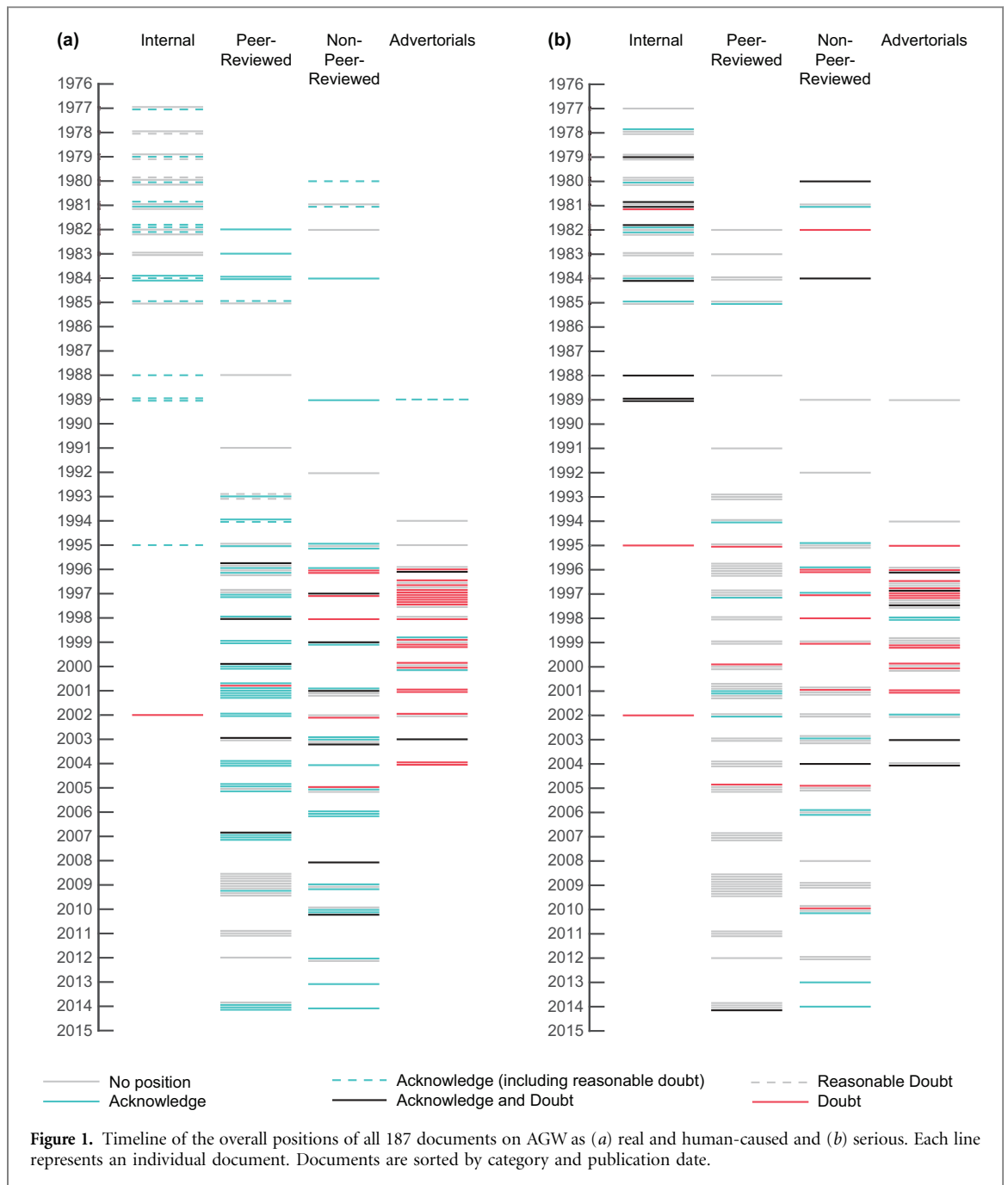
2.1.2. 'Serious'

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 Acknowledge (including reasonable doubt) (dashed blue). 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.

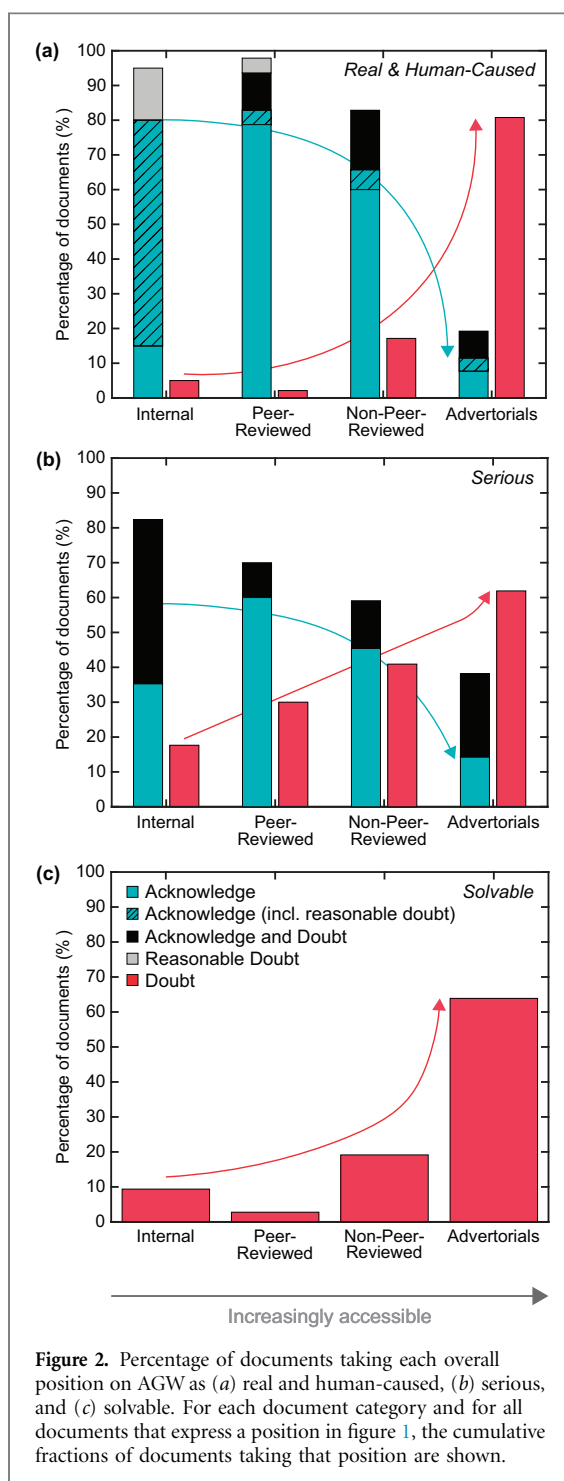


Figure 2. Percentage of documents taking each overall position on AGW as (a) real and human-caused, (b) serious, and (c) solvable. For each document category and for all documents that express a position in figure 1, the cumulative fractions of documents taking that position are shown.

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 Keshgi, was a contributing author), which observed a ‘discernible human influence on global climate’ [15, 76]. Keshgi 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.

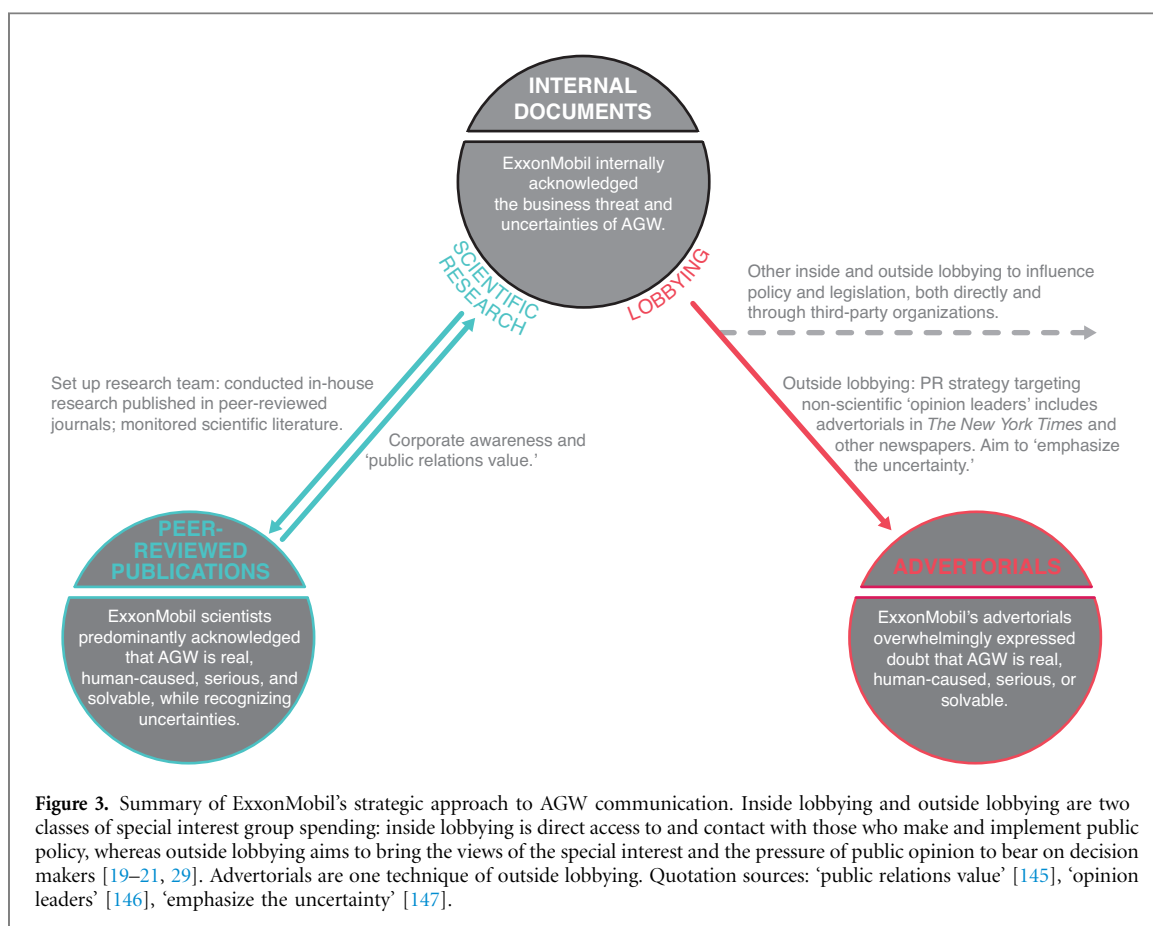
INTERNAL	1979 [82]	‘The major conclusion from this report is that, should it be deemed necessary to maintain atmospheric CO ₂ levels to prevent significant climatic changes, dramatic changes in patterns of energy use would be required. World fossil fuel resources other than oil and gas could never be 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 Khesghi 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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