

Carbon producers' tar pit: dinosaurs beware

The path to holding fossil fuel producers accountable for climate change & climate damages

Institute for New Economic Thinking: Plenary Conference in Edinburgh

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Abstract. The project to quantify the contribution to atmospheric carbon dioxide and methane arising from the operational emissions of fossil fuel company supply chains and the sale of carbon fuels to consumers began with an analysis of John Rockefeller's Standard Oil Company from 1882 to 2002 under the aegis of the Climate Justice Programme. The report, and the modeling of ExxonMobil's contribution to temperature change and sea level rise, was published by Friends of the Earth UK in 2005. This paper traces the evolution of the project, its methods and results, the milestones, and the reactions of industry and government up to the recent publication of an attribution study in *Climatic Change*, corporate accountability for climate change (and from which year does the clock on accountability start?), industry climate denial efforts, their moral obligation to lead on decarbonizing the world economy, potential litigation risks for climate damages and reparations, and lawsuits filed by citizens, counties, and cities in California and elsewhere.

Introduction

It is broadly accepted that anthropogenic climate change presents a serious threat to the health, prosperity, and stability of human communities, and to the stability and existence of non-human species and ecosystems. The international legal framework established in 1992 to prevent "dangerous anthropogenic interference" with the climate system has focused attention on the role of nation-states, and led to the Paris Accord in 2015 with commitments by 197 nation-states to cut their greenhouse gas (GHG) emissions in alignment with not exceeding 2°C of global warming and an "aspirational" target of "well below" 2°C. Current climate change is primarily driven by historic emissions (Allen et al. 2009, Matthews et al. 2009; Wei et al. 2012; IPCC 2013), and the developed states with the largest attributed historic emissions have assumed primary responsibility for taking the lead in reducing global emissions.

The rationale for attributing responsibility for global climate change was embodied in the 1992 UN Framework Convention on Climate Change, in which the "Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof." (my emphasis.)

The burdens and responsibilities are lain at the footsteps of the richest nations with the largest historical carbon footprint. The United States has contributed 25% of global CO₂ since 1800, and thus bears the largest obligation to lead. (China, the culprit usually chastised by Congressional climate denialists, is responsible for 11% of historic emissions.) The Paris Accord will prosper under saner leadership than President Trump's anti-science and anti-regulatory administration, as evidenced by "We Are Still In" commitments by thousands of companies, universities, states, and cities across the U.S. and the shift from coal to natural gas and renewables for electricity generation.

U.S. withdrawal from the Paris Accord and the dearth of positive policy initiatives after significant progress under the Obama administration opens the prospect for solutions from other quarters. While the retrograde policy vacuum dominates in the United States, the alternative pathways to leverage action by the elephants in the room — the fossil fuel companies — exist around the world.

There is another way of looking at historical obligations: the culpability of corporations that extracted the fossil fuels, refined them into marketable fuels, and distributed their products to consumers in every nation on earth. Why attribute responsibility on companies that, in their own words, provide materials in high demand and that fuel social and economic progress? Because these companies have a moral and legal obligation to warn consumers and society if their products are defective or dangerous. They operate with at-risk social operating licenses, and motivated to burnish their brands. Investors increasingly demand compliance with global climate targets and transparency from companies with respect to climate performance and potential stranded assets.

For example, ExxonMobil's own scientist have known since the 1970s that increased fossil fuel use would destabilize the climate and imperil the company's future production of oil and natural gas. Exxon's management was made aware of these findings, but instead of transparency the company funded campaigns to sow doubt about climate science, defeat climate legislation, delay action on climate, and published a series of "advertisements" intended to mislead the public (Supran & Oreskes, New York Times; see also Climate Deception Dossiers (Union of Concerned Scientists), and Smoke & Fumes (Center for International Environmental Law)). ExxonMobil was not alone in being aware of the threat of climate change from continued use of fossil fuels (Banerjee et al. 2016). President Johnson warned in a message to Congress in 1965 that "this generation has altered the composition of the atmosphere on a global scale through ... a steady increase in carbon dioxide from the burning of fossil fuels." (PSAC 1965, Oreskes & Conway 2010). Trade associations and industry-funded non-profits such as the American Petroleum Institute, the Global Climate Coalition, and the Green Earth Society challenged the emerging consensus on climate change and argued for the benefits of global warming on crops and warmer winters. Such nonsense is still argued in the United States by prominent advisors to the Trump Administration and by members of Congress.

Considerable wealth has accumulated to companies that produce the fuels sold on the international market. For this reason, the present analysis focuses on the world's largest investor-owned and state-owned carbon producers, whether situated in Annex I or non-Annex I nations, and invites consideration of the suggestion that some degree of responsibility for both cause and remedy for climate change rests with those entities that have extracted, refined, and marketed the preponderance of the historic carbon fuels.

The question for a responsible company was then, as it is now, how to avoid catastrophic climate change and reduce the company's liability for damages. None of the major domestic or international fossil fuel companies took meaningful steps to avert the train-wreck we are now the victims of: multiple hurricanes ravaging the Caribbean and Gulf of Mexico, torrential rain and floods in India, Puerto Rico, and Houston, destructive wild fires, deadly heat-waves in Europe and Asia, and worse to come — *for centuries*. Use of fossil fuels intensifies storms and the loss of life and treasure (Mann 2017). While human activities *exacerbate* rather than *cause* storms, it is time, as MIT atmospheric scientist Kerry Emanuel said recently, to "stop calling these hurricane disasters 'natural.'"

It is not simply nations and consumers that are responsible for climatic changes and the ensuing damages to nature, wealth, and security, but the fossil fuel producers, too.

Legacy responsibilities

I first got curious in 2003 about the proportion of atmospheric carbon dioxide that is attributable to the world's largest oil, natural gas, and coal companies and the carbon fuels they produced. My research was funded by the Climate Justice Programme (CJP, then based in London) and I focused on the history of oil and gas production and the quantification of attributable emissions of a single oil and gas firm — Standard Oil to ExxonMobil from 1882 to 2002. I developed a methodology for estimating direct operational emissions of carbon dioxide and methane from the supply chain — from exploration and processing to finished carbon fuel products — and, most importantly, of emissions from the carbon fuels *used as intended* by the company's worldwide customers. My results were fed into a simple climate model and summarized in *Exxon's Climate Footprint: the contribution of Exxon-Mobil to climate change since 1882* (Friends of the Earth International 2004).

Corporations ascribe to the guidance in the *Greenhouse Gas Protocol* (WRI 2004) regarding their accounting and mitigation boundary — typically direct (scope 1: from fuel used in owned or leased buildings, facilities, vehicles, and aircraft) and indirect (scope 2: from purchased electricity and steam) operational emissions of greenhouse gases. These are the sources most companies commit to inventory and, to varying degrees, commit to reduce or offset. Not so with product-related emissions, however, which is the underlying objective of the set of analyses begun in 2003: to identify the largest producers of fossil fuels and to quantify direct operational and product-related emissions from extracted and marketed carbon fuels by these same companies by fuel and by year. We have thus quantified the climate legacy of these companies from their inception to the present.

CJP subsequently funded an expansion of the project to trace half or more of historical industrial CO₂ emissions to the primary carbon producers, as discussed below. This expanded scope required gathering production data for several dozen companies over many decades, and was intermittently funded from 2004 to the project's completion in 2013, with a final round of funding by Greenpeace International and CJP. A thorough peer review confirmed the robustness of the methodology, which is essential for standing up to industry scrutiny, public credibility, and legal standing.

Methodology

For tractability, a threshold of 8 million tonnes carbon per year (MtC/y) for fossil fuel production was established.¹ This resulted in the identification of 90 entities: 50 investor-owned companies, 31 state-owned enterprises, and 9 current or former centrally planned states. Of these 90 entities 56 are crude oil and natural gas producers, 37 are coal extractors (including subsidiaries of oil & gas companies), and 6 are cement producers. Headquartered in 43 countries, these entities extract resources from every oil, natural gas, and coal province in the world, and process the fuels into marketable products that are sold to consumers in every nation on Earth.

Company production records were retrieved from publicly available annual reports from university and public library collections in Europe, North America, Africa, and Asia, from company websites, company reports filed with the U.S. Securities and Exchange Commission, company histories, and other sources. The carbon content of each entity's annual production of coal, oil, natural gas liquids, and natural gas — typically reported in physical units (coal in Mt, oil in Mb, and gas in Bcf) — was calculated using IPCC, United Nations, International Energy Agency (IEA), and U.S. Environmental Protection Agency (EPA) carbon factors to quantify the annual emissions traceable to each entity. Historically complete records were sought from the earliest available (the earliest is from 1854) through 2010. Where mergers or acquisitions occurred, carbon production and emissions prior to

¹ 8 MtC is equivalent to the carbon content of 69 million bbl (Mb) of oil or 13.8 Mt thermal coal.

the date of acquisition are attributed to the extant company. We included six large cement companies for their liberation of CO₂ from calcining of limestone CaCO₃ into cementitious products.

The methodology deducts for the non-energy uses of liquids, gases, and coal (subtracting ~8% of liquids production for petrochemicals, road oil, lubricants, etc.), while accounting for short-term emission to the atmosphere of incinerated plastics (~40 Mt/y), oxidation of lubricants, and so forth.

Table 1. Combustion emissions factors.

Energy source	Carbon tC/unit	Carbon dioxide tCO ₂ /unit
Crude oil & NGLs	101.4 kgC/bbl	371.4 kgCO ₂ /bbl
Natural gas	14.6 kgC/kcf	53.4 kgCO ₂ /kcf
Lignite	328.4 kgC/tonne	1,203.5 kgCO ₂ /t
Subbituminous	495.2 kgC/t	1,814.4 kgCO ₂ /t
Bituminous	665.6 kgC/t	2,439.0 kgCO ₂ /t
Anthracite	715.6 kgC/t	2,621.9 kgCO ₂ /t
"Metallurgical coal"	727.6 kgC/t	2,665.9 kgCO ₂ /t
"Thermal coal"	581.1 kgC/t	2,129.3 kgCO ₂ /t

Crude oil: prior to non-energy deduction & adjustment for NGLs: 115.7 kgC/bbl, 423.8 kgCO₂/bbl;
Gas: prior to non-energy deduction: 14.86 kgC/kcf , or 54.44 kgCO₂/kcf; (kcf = thousand cubic feet).

Direct operational emissions — which comprise ~10% of oil and gas and ~8% of coal company total attributed emissions — include:

- CO₂ from flaring (of raw gas associated with oil wells, safety flares on drilling platforms);
- CO₂ vented from natural gas processing plants (CO₂ entrained in raw gas and vented);
- CO₂ from a company's use of own fuel in refineries, processing plants, compressor stations, vehicles, trucks, aircraft, drill rigs, offshore platforms, ships, and miscellaneous equipment;
- Fugitive and vented methane from wellheads, gas processing plants, valves & seals, storage tanks, refineries, distribution infrastructure, and tens of thousands of points between the well and the company gates;
- Vented methane from coal mining operations and coal mines, typically vented for safety reasons, and seldom captured and utilized or flared.

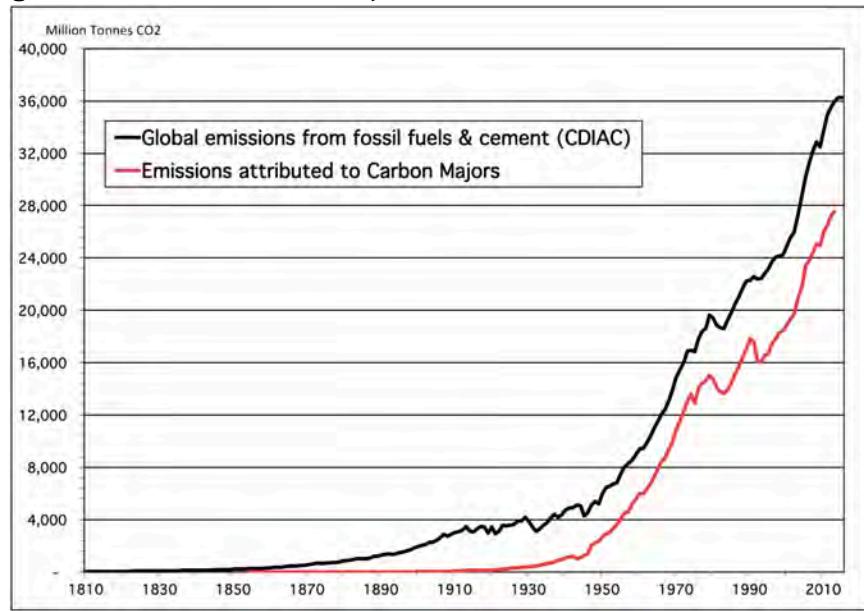
The methodology, the peer-review process, and conservatisms adopted for the Carbon Majors accounting protocol is discussed in the Supplementary Materials to [Heede 2014](#), and Heede 2013.

Results of Carbon Majors study (2014)

The 2014 analysis documented a total of 914 billion tonnes of CO₂-equivalent (GtCO₂e) traced to 90 international entities based on historical production records dating from 1854 to 2010. These entities cumulatively produced 985 billion barrels (Gb) of crude oil and NGLs (79 Gb were for non-energy uses), 2,248 trillion cubic feet (Tcf), and 163 billion tonnes (Gt) of various ranks of coal. The emissions traced to the carbon majors represented 63 percent of global industrial CO₂ and methane from fossil fuel combustion and cement between 1751 and 2010. Attributed emissions from crude oil and NGLs totaled 366 GtCO₂ from 55 entities representing 77 percent of the global estimate of oil & NGL emissions since petroleum production began (Boden, Andres, & Marland / CDIAC 2017). In table 2 we compare each entity's historical product-related and operational emissions to global fossil fuel and cement emissions in the CDIAC database of industrial CO₂ & CH₄ emissions in column "percent of global 1751-2013."

In Figures 1, 2, and 3 and Table 2 are updated results to 2013 production and attributed emissions (Heede 2014b, Lima Peru). The original Carbon Majors quantification and attribution was updated by CAI and CDP in 2017 (Griffin 2017, Griffin et al. 2017, Magill 2017) to 2015 production and emissions data, with slight modifications to the methodology.

Figure 1. Global and Carbon Major entities' CO₂ emissions, 1810-2013.



Global fossil fuel and cement emissions of CO₂ from CDIAC (black line).
Results of all Carbon Major entities' emissions of CO₂ and methane (red line).

Table 2. Cumulative emissions attributed to major fossil fuel & cement producers, 1854-2013, Top 20 IOC & SOE

Entity	Product-related CO ₂ MtCO ₂	Flaring, own fuel, vented CO ₂ MtCO ₂	Fugitive methane MtCO _{2e}	Total emissions MtCO _{2e}	Percent of global 1751-2013
1. ChevronTexaco, USA	47,312	1,505	3,430	52,247	3.34%
2. Saudi Aramco, Saudi Arabia	47,786	1,171	2,488	51,445	3.29%
3. ExxonMobil, USA	43,239	1,603	3,714	48,557	3.10%
4. BP, UK	33,761	1,064	2,426	37,251	2.38%
5. Gazprom, Russian Federation	28,518	2,343	5,539	36,400	2.33%
6. Royal Dutch Shell, The Netherlands	28,802	1,041	2,327	32,171	2.06%
7. National Iranian Oil Company	28,935	856	1,867	31,658	2.02%
8. Pemex, Mexico	19,700	643	1,420	21,762	1.39%
9. Coal India	16,677	0	1,413	18,090	1.16%
10. ConocoPhillips, USA	15,300	687	1,566	17,553	1.12%
11. Peabody Energy, USA	12,785	0	1,083	13,869	0.89%
12. Petroleos de Venezuela	12,640	356	771	13,767	0.88%
13. Total SA, France	11,633	389	862	12,884	0.83%
14. PetroChina, China	11,103	336	736	12,175	0.78%
15. Kuwait Petroleum Corp.	10,917	252	531	11,700	0.75%
16. Abu Dhabi	10,163	310	678	11,151	0.71%
17. Sonatrach, Algeria	8,882	442	1,015	10,340	0.66%
18. CONSOL Energy, USA	8,519	5	729	9,254	0.59%
19. BHP Billiton, Australia	7,908	69	672	8,649	0.55%
20. Iraq National Oil Company	7,436	158	327	7,921	0.51%

Scope 3: product emissions; Scope 1: direct operational emissions (flaring, vented, fugitive, etc.). Heede 2014b.

Global CO₂ emissions from the combustion of fossil fuel and cement manufacturing ("industrial emissions") are derived from the comprehensive CDIAC database (Boden et al.) that begins with the emission of ~11 MtCO₂ in 1751 from coal combustion in early steam engines and rose to 36,265 MtCO₂ in 2015. The ninety Carbon Majors are compared to global industrial CO₂ in Figure 1 and Table 2. Note that we focus on shares of industrial emissions and exclude other sources of CO₂, methane, and the other greenhouse gases, such as landfill methane or net forestry losses. Figure 2 shows the emissions of six large oil and gas companies 1910-2013 and the shifting dominance of large investor-owned companies through the early 1970s and the rising share of Saudi Aramco and other OPEC producers in the 1970s (Russia/Gazprom is not an OPEC member). Legacy emissions of the largest 20 companies are shown in percent of global 1751-2013 in Fig. 3.

Figure 2. Top six entities' CO₂ emissions and methane, 1910-2013.

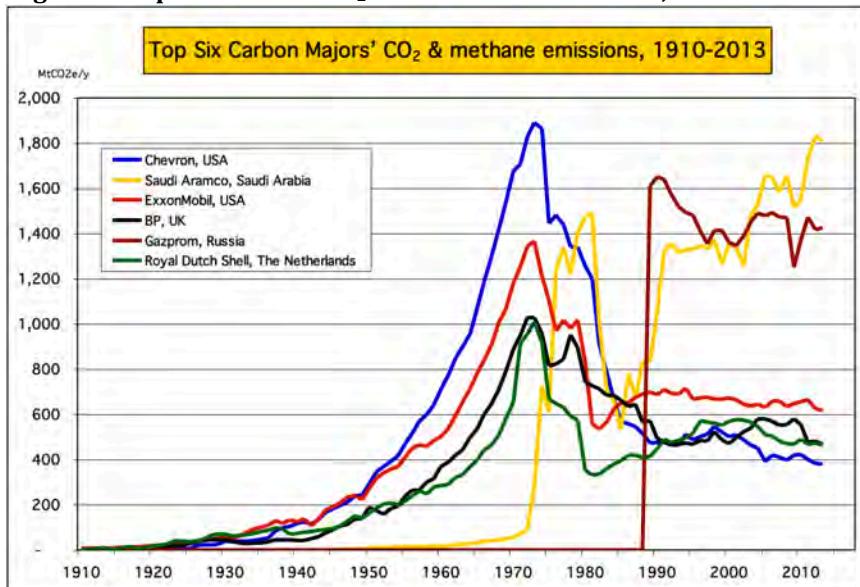
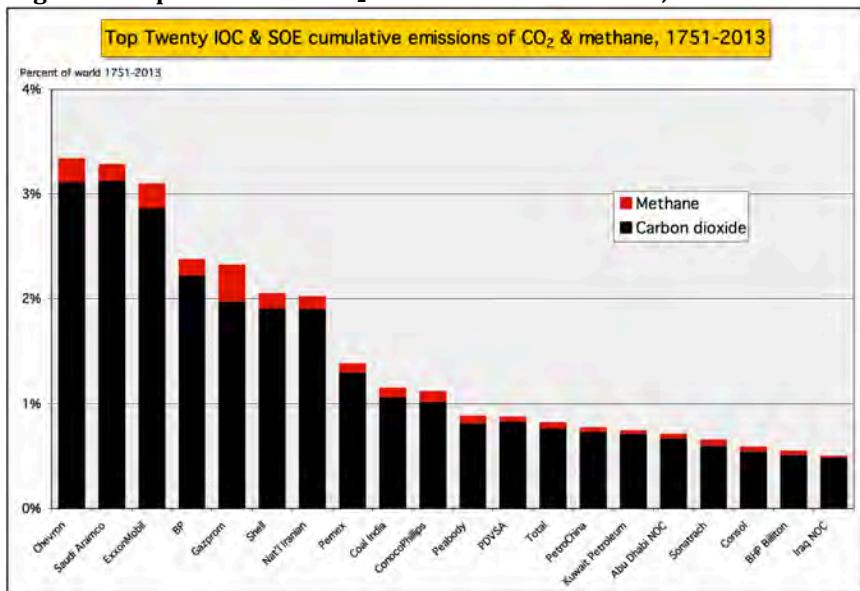


Figure 3. Top six entities' CO₂ emissions and methane, 1910-2013.



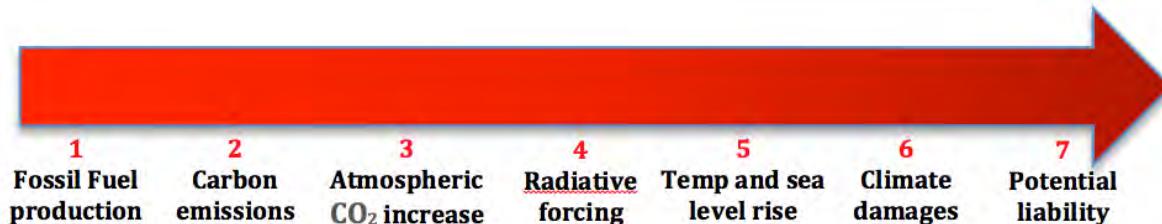
To this observer it is indisputable that each entity has material responsibility for extracting and marketing carbon fuels and is clearly responsible for its operational emissions. I contend these companies also have substantial responsibility for emissions of CO₂ from its globally marketed products. In order to establish causal responsibility for a proportion of the climate changes and climate-related *damages* from human emissions of greenhouse gases we must first analyze the effects that emissions traced to individual carbon producers have on the atmosphere.

We collaborated with colleagues and scientists at Union of Concerned Scientists and University of Oxford to model the increase in atmospheric concentration of CO₂ and methane (accounting for the cooling effects of aerosol pollution from fossil fuels), the increased radiative forcing, the rise in global mean surface temperature, and the rise in global sea levels attributable to each company's fossil fuel production by year. Our team carefully designed the modeling and analysis, drafted the paper, revised the approach and the model upon review by several peers, and submitted the paper

to further comprehensive peer reviews over a period of nearly four years. The paper was published in September of this year in *Climatic Change* (Ekwurzel et al. 2017).

The Carbon Majors paper (Heede 2014) accomplished the 1st and 2nd phases of using scientifically valid approaches to apportioning real-world climate damages to carbon producers. In September we made a leap forward in holding producers proportionally accountable (Figure 4).

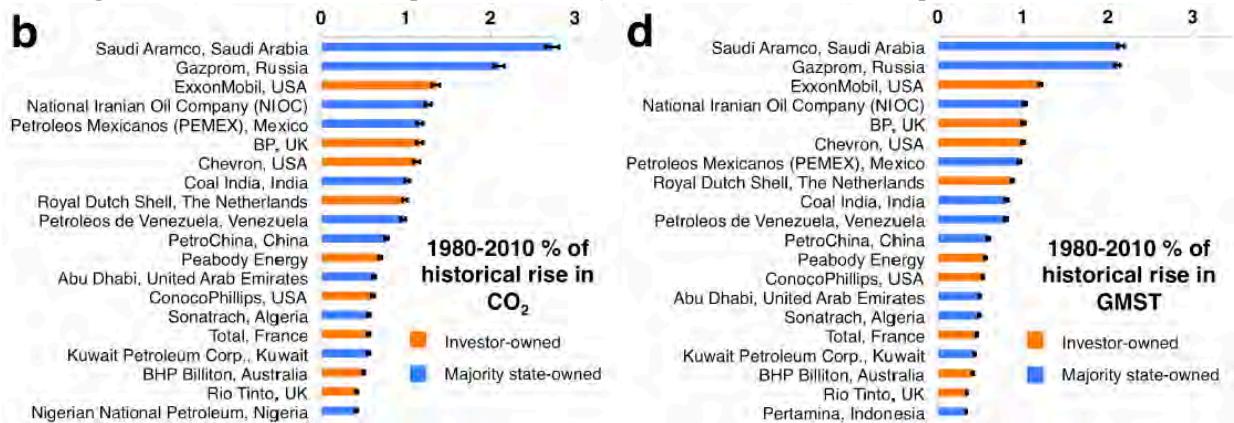
Figure 4. Sequence of project milestones from fossil fuel production to potential liability



Attribution study (2017)

In September we published an analysis attributing to each major carbon producer the increase in atmospheric CO₂ concentration (ppm) and radiative forcing that would drive global temperature and sea level rise, based on each company's historical emissions profile developed in Heede 2014 (Ekwurzel et al. 2017). The team included climate modelers and scientists from Union of Concerned Scientists, University of Oxford, and Climate Accountability Institute.

Figure 5: Contribution of Top 20 Carbon Majors to rise in CO₂ and temperature, 1980-2010



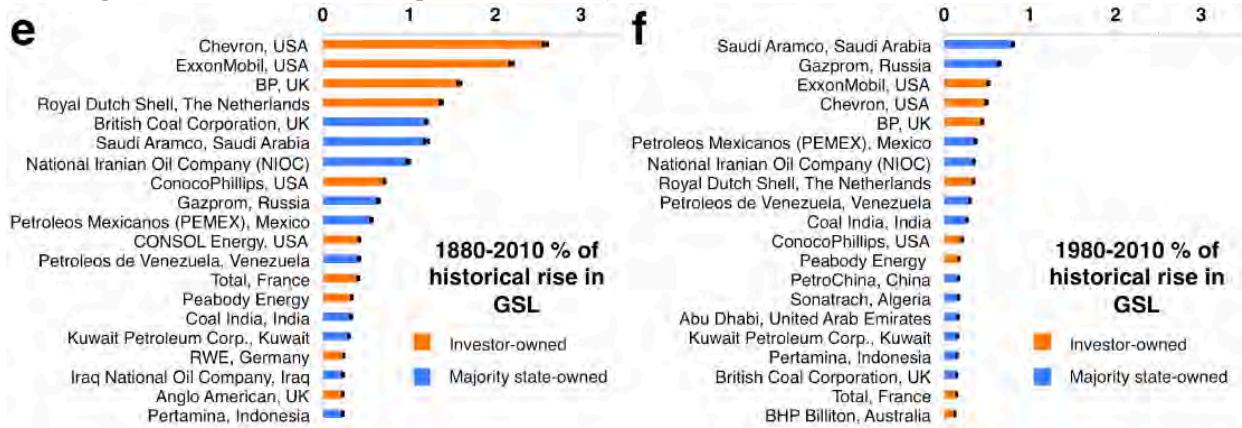
Ekwurzel et al. 2017, Fig. 2: 1980-2010 rise in CO₂, 1% = 1.03 ppm (b); mean surface temperature, 1% = 0.008 °C (d)

Using a simple global energy-balance coupled climate-carbon-cycle model (Millar et al. 2016), we estimated the CO₂ concentration, surface temperature, and sea level rise attributable to emissions of carbon dioxide and methane traced to each entity. The model is sensitive to the *timing* of the attributed emissions, since methane decays in the atmosphere, aerosol emissions lead to short-term cooling, carbon cycling, and so forth. The team selected two periods of time for analysis of climate impacts: the first (1880-2010) allows for long-term data on anthropogenic emissions, CO₂ concentration, temperature response, and sea level rise; the second (1980-2010) coincides with rising awareness of the climate risks of continued fossil fuel use following the publication of the seminal U.S. National Research Council report *Carbon Dioxide and Climate* (NRC 1979; discussion in Frumhoff et al. 2015, and Banerjee 2015). By 1980, or earlier,² no company can claim to be unaware of the *risks* of being in the carbon extraction business without foundering on willful ignorance.

² Arguably earlier than 1979: consider the report to the White House (President's Science Advisory Committee, 1965), or the Stanford Research Institute report prepared for American Petroleum Institute in 1968 that warned that if "CO₂ levels continue to rise at present rates, it is likely that noticeable increases in temperature could occur." Svante Arrhenius had

The focus of the climate modeling summarized in the Ekwurzel paper is on the consequences of emissions traced to the ninety major carbon producers from 1980 to 2010. We show that CO₂ concentration, global temperature, and sea level rise attributable to the carbon and methane traced to the ninety Carbon Majors accounts for 0.28 °C (35.1% of total GSMT increase of 0.8 °C) and to global sea level rise of 5.7 cm rise since 1880 and a 2.38 cm rise for carbon production since 1980.

Figure 6: Contribution of Top 20 Carbon Majors to sea level rise 1880-2010 and 1980-2010



Ekwurzel et al. 2017, Fig. 2: historical rise in global sea level, 1880-2010 (e) and 1980-2010 (f), in percent; 1% = 1.77 mm.

Table 3. Top Twelve carbon majors: CO₂, ppm CO₂, temperature, sea level rise, & land loss, 1980-2010

Entity	Emissions GtCO ₂	CO ₂ concentration ppm	Temperature °C	Sea level mm	Land loss km ²
Saudi Aramco	36.6	3.23	0.0174	1.43	602
Gazprom	27.2	2.16	0.0171	1.14	482
ExxonMobil	18.7	2.78	0.0097	0.92	386
National Iranian	16.8	1.92	0.0083	0.62	261
BP	16.2	2.19	0.0081	0.80	335
Chevron	16.0	2.97	0.0081	0.88	370
Pemex	15.7	1.37	0.0078	0.65	274
Royal Dutch Shell	13.4	1.87	0.0071	0.61	256
Coal India	13.2	1.11	0.0065	0.47	200
Petroleos de Venezuela	13.1	1.12	0.0065	0.54	226
Peabody Energy	9.0	0.86	0.0045	0.30	128
ConocoPhillips	8.3	1.03	0.0043	0.38	158
Subtotal	204.2	22.61	0.1054	8.73	3,678
Carbon Majors, 1980-2010	754.9	43.84	0.400	23.80	10,041
Global, 1880-2010 ³	1,317.8	103.00	0.850	176.60	74,379

The twelve companies in Table 3 whose operational and product-related emissions since 1980 have already inundated an estimated 3,678 km² of land around the world's shorelines (10,041 km² if all carbon majors are taken into account) — mostly, of course, in remote and sparsely populated

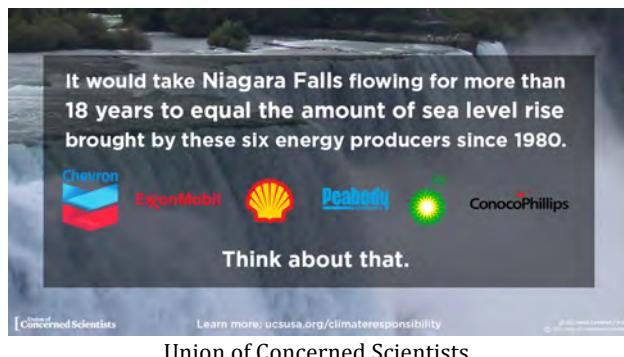
warned of global warming in his paper "on the influence of carbonic acid in the air upon the temperature of the ground" in 1896 with uncanny accuracy regarding the sensitivity of global temperature from the doubling of atmospheric CO₂ concentration (though with scant appreciation of the fantastical rise of fossil fuel use in the decades ahead [from 419 MtC in 1896 to 9,897 MtC in 2015; CDIAC]). Carroll Muffett, President of the Center for International Environmental Law (and a Climate Accountability Institute board member) told *InsideClimate News* that from "a products liability perspective, these documents raise potential claims that oil companies failed to warn consumers about a potentially serious risk linked to their products. Once the companies learned this science, they can't unlearn it. Everything they did after this is done against the backdrop of the information they have from at least the 1950s onward." (Banerjee et al. 2016).

³ Global data sources: increase 1880-2010: 98.6 ppm (IPCC 2013); the model simulations yield an increase of 103 ppm (Ekwurzel Fig 1); mean surface temperature: best fit ~0.8 °C for 1880-2010, of which all carbon majors 0.4 °C; sea level rise: Kopp (2016 reports a twentieth-century GSL of 12-15 cm, "the model simulation for best estimate parameters with full historical forcing yields a GSL over 1880 to 2010 of ~18 cm," and "Removing the annual emissions traced to 90 major carbon producers from the best estimate full historical forcing case shows that the combustion of their products from 1880 to 2010 led to a 5.7 (±0.1) cm increase in GSL, 32 (±0.4)% of the total anthropogenic contribution to increased GSL. Less than half (~42%) of this is due to major carbon producer-traced emissions of recent origin." Combustion of their products between 1980 and 2010 led to a 2.38 (±0.03) cm increase, 13.5 (±0.2)% of total GSL increase 1880-2010.

areas.⁴ Yet valuable private and corporate assets are threatened (and require mitigation) as well as natural shorelines of ecological value. Of the global land areas already inundated with emissions attributed to the twelve carbon majors in Table 3 from 1980 forward (3,678 km²), 1,549 km² are in North America and 577 km² in Europe (42% and 16% of global land loss). In comparison, Puerto Rico, recently ravaged by hurricanes Irma and Maria, covers 9,104 km², Rhode Island 2,707 km², Estonia 45,336 km², and Monaco 2 km². Among the Pacific island nations threatened with climate refugee status from inundation in the coming decades, Tuvalu is 26 km², Marshall Islands 181 km².

While the contributions of individual companies are small, when it comes to the most visible impact of sea level rise — estimated as having risen 18 cm in the twentieth century — these numbers nonetheless represent startling loss of land around the world's 356,000 km coastline (CIA 2016).⁵

The ocean covers 362 million km², thus a 1 mm SLR is equivalent to 362 billion m³ or 362 km³ of sea water. The combined sea level rise attributed to six of the investor-owned fossil fuel companies — Chevron, ExxonMobil, Royal Dutch Shell, Peabody, BP, and ConocoPhillips — is equivalent to the water flowing over Niagara Falls for 18 years.⁶ To quote UCS: "Think about that."



Union of Concerned Scientists.

What are such losses worth to injured parties, who should pay, and will the fossil fuel industry be held accountable for any proportion of damages?

Carroll Muffett, President of the Center for International Environmental Law, commented that:

"Like the Carbon Majors analysis that it builds on, this report demonstrates the growing precision with which major carbon producers' responsibility for climate change and climate impacts can be quantified, allocated, and, ultimately, litigated. Government investigators and private attorneys around the world will be parsing these findings carefully. Investors and decision-makers would be well-advised to do the same."

Industry action and reaction

The oil and gas industry, the coal industry, and related trade associations have spent decades deceiving the public and policymakers about climate science for the purpose of perpetuating the profitability of the carbon economy without restraint. Standard corporate behavior in the face of concerns over products such as lead, asbestos, DDT, tobacco, and carbon (Oreskes & Conway 2010).

⁴ These are preliminary calculations of estimated land loss attributed to emissions traced to major carbon producers as discussed above. I base the calculations on a database of global land inundation from a projected 1-meter sea level rise, 90-meter resolution of coastlines, and scaled down to the 2.38-cm SLR in Ekwurzel et al. paper for 1980-2010. In the CIESIN database, **global SLR of 1 m equates to 421,174 km² of inundated land** (Center for International Earth Science Information Network, viewed Oct 2017), and 1 mm equates to 421 km², assuming that the slope of inundated lands is equal to the slope of projected SLR. See Table 3 for SLR attributed to each major carbon producer, 1980-2010. Any errors of interpretation or use of the CIESIN data is the author's. The CIESIN model also has uncertainties; see Mondal & Tatem.

⁵ Other sources estimate the world's shorelines at 1.6 million km at the resolution required to discern bays, islets, and fjords — in other words, real-world coastlines. For example, Norway's "official" coastline is 25,148 km, but higher resolution imaging shows 83,281 km (CIA 2016), and new research puts it at 101,400 km (Klinkenborg, 2013).

⁶ Wikipedia cites an average flow rate of 2,400 m³/s, which equals an annual flow of 74.8 billion m³ = 74.8 km³, and 1,347 km³ over 18 years. The six cited companies total 3.88 mm of SLR from 1980-2010, which converts (362 km³/mm SLR) to 1,404 km³. Source: https://en.wikipedia.org/wiki/Niagara_Falls. See also https://en.wikipedia.org/wiki/Niagara_River

Companies shifted strategy once public acceptance, based on corporate disinformation, had taken root that science was too uncertain for legislative action on climate. The public remains deeply confused to this day, though improving (Leiserowitz et al.). Conservatives and climate deniers are quick to raise the spectre of the costs and employment consequences of climate action, regardless of the evidence that tackling climate change grows the economy and employment.

Most, if not all, oil and gas companies measure, mitigate, and report on emissions of CO₂ and methane in annual sustainability reports and to third parties such as GRI or CDP. Most companies have made significant progress in reducing direct and indirect operational emissions (WRI Scope 1 and Scope 2 sources) over the last decade or two Fig. 7a), although few have reduced the *carbon intensity* of their supply chains (Fig. 7b) (Heede, forthcoming) — much less emissions from carbon resources extracted, refined, and delivered to consumers worldwide as discussed above (Fig. 2 & 8).

Figure 7a: Operational emissions (scope 1 + 2)

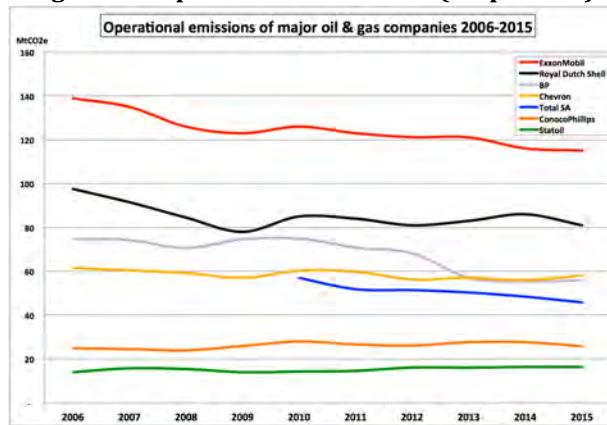
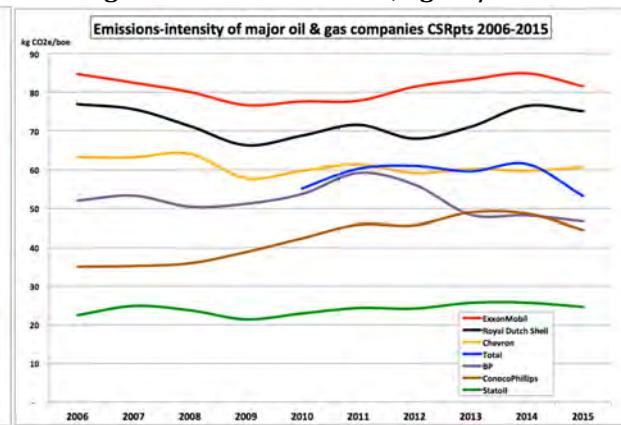


Fig. 7b: carbon intensities, kgCO₂/boe

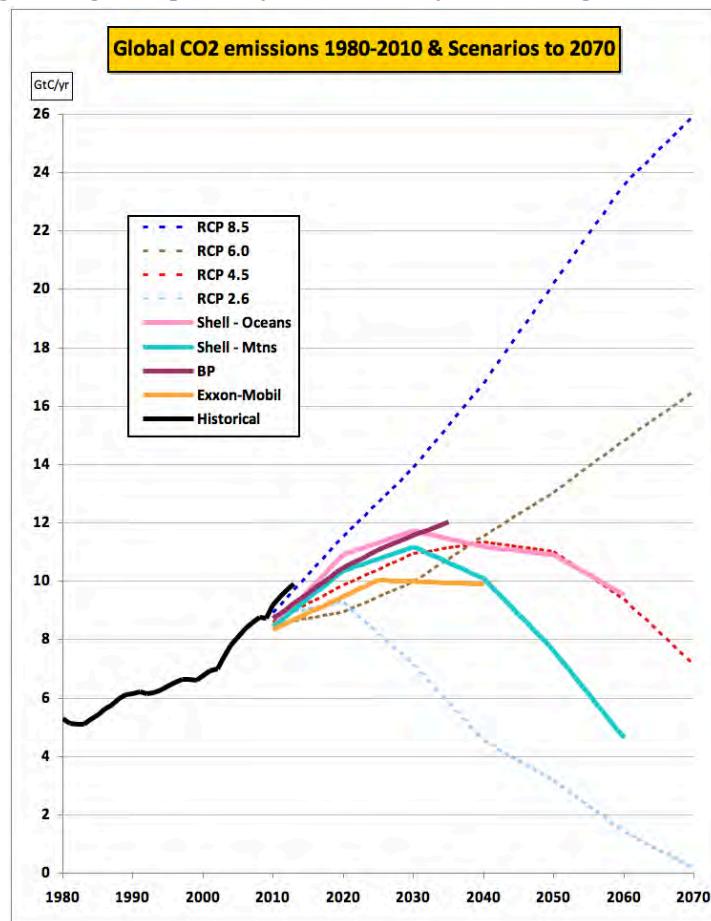


A more threatening reaction is to harass research, scientific, and advocacy organizations, either indirectly (through Breitbart News or other climate denial bloggers) or directly, with subpoenas. Climate Accountability Institute, me personally, and a number of our colleagues and funders have been harassed by investigations and subpoenas from the U.S. House of Representatives (Committee on Science, Space, and Technology) by Chairman Lamar Smith, a proud climate denier (Smith 2017: “we are seeing beneficial changes to the earth’s geography”) and a profligate issuer of subpoenas, as well as subpoenas from ExxonMobil. Discretion prevents me from elaborating here, except to say that the subpoenas relate to the investigation by New York AG Schneiderman and Mass AG Healey of ExxonMobil for potential consumer and investor fraud (Gillis & Krauss 2015, Schwartz 2016a). Mr. Smith, for his part, was investigating our alleged coordinated attempt to “deprive companies, non-profit organizations, and scientists of their First Amendment rights and ability to fund and conduct scientific research free intimidation and threats of prosecution.” Not the First Amendment Rights of research scientists and advocacy organizations, mind you, but ExxonMobil’s.

Most oil and gas and coal companies do invest in low- and non-carbon energy sources and other forms of mitigation — but for most it is a minuscule percentage of capital expenditures (typically <1-2%), and few companies are investing seriously in carbon capture and storage. Moreover, most major oil & gas companies project dramatic *overshoot* of global CO₂ emissions in the decades ahead (ExxonMobil, BP, Royal Dutch Shell; see Frumhoff et al. 2015, and Carbon Tracker 2014). Figure 8 shows emission pathways for four “representative concentration pathways” — RCP 2.6, 4.5, 6.0, and 8.5 of IPCC scenarios — of which RCP 2.6 is considered close to the pathway for global warming guardrail of ≤2°C. The figure shows the overshoot forecasts of major oil & gas companies, which are investing heavily (>\$700 billion per year) in new resources and reserves, while claiming (without foundation, in my view, see Heede & Oreskes 2016) that meeting growing demand for carbon fuels is justified to alleviate energy poverty. The implicit threat is that the companies aim to continue to

profit from maximizing production over several decades, relying on the continuance of policies inadequate to curtail carbon emissions in line with the 2°C guardrail, much less 1.5°C.

Figure 8: global pathways and industry forecasting of emissions.



Frumhoff et al. 2015.

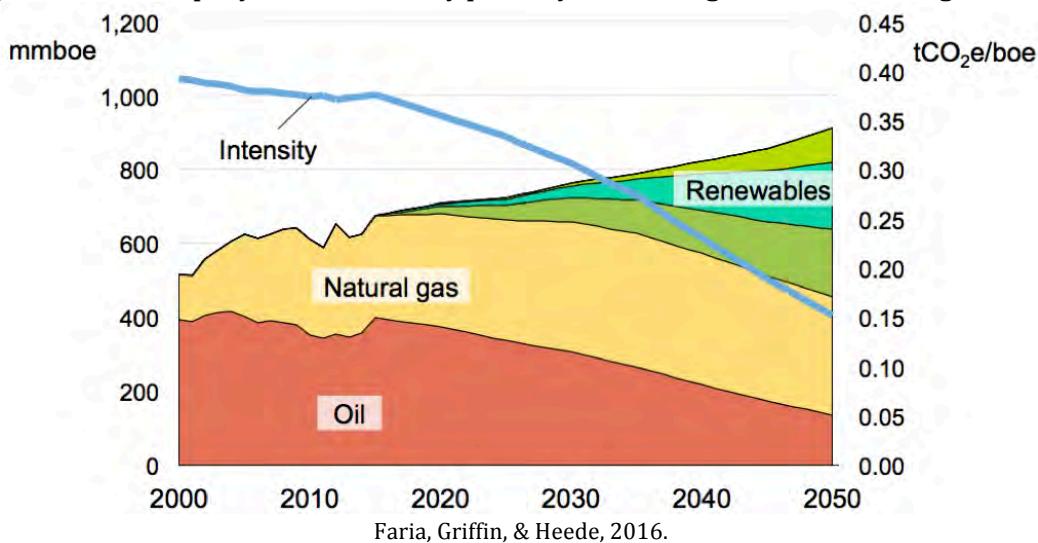
Science-based targets for oil, natural gas, and coal companies

If we are to achieve global reductions in energy-related CO₂ and methane emissions that meet the objectives of the Paris Accord, then it is incumbent, in this observer's opinion, on industry to take the lead, not simply wait for political leaders to make the needed policy initiatives. The current set of policy initiatives are inadequate to the task (Germanwatch 2017, Rogelj et al. 2016), particularly in the United States (where the Trump Administration's deplorable policies are intended to *increase* fossil fuel production, consumption, and exports), Canada, Japan, Russia, China, and Australia. It is time for the carbon companies to assert leadership rather than the passive do-nothing attitude they have been profitably hiding behind for decades.

Leading oil & gas companies are beginning to see the writing on the wall that aligning production and investment with science-based targets is a question of responsiveness to investor concerns, and to regulators and litigators, and perhaps even an existential inquiry for how to survive in the 21st Century. *Progressive* companies go a good deal further in orienting their strategies to prosper under severe climate restraints. I rank Statoil, Total SA, Shell, and BP as the most visionary in this regard and that support the transition with significant investment in a shift to natural gas (many companies are doing this; net benefits depend on CH₄ leakage), reducing operational emissions, mitigation, carbon capture and storage, and, most importantly, low- or zero-carbon alternatives.

We analyzed the reserves and investment options for one oil & gas company in order to understand its carbon intensity and emission pathway out to 2050 (Faria et al. 2016; Figure 9).

Figure 9: O&G company carbon intensity pathway for meeting science-based target of $\leq 2^{\circ}\text{C}$



Similar analyses will increasingly be conducted by progressive oil & gas companies and by Climate Accountability Institute and our colleagues. The initial focus is likely to be on measures to reduce operational (scope 1 & 2) sources that align company emissions with the 2°C pathway (or less); product emissions will also need to be accounted for as companies learn to aim higher.

Legal implications

The scientific contributions toward the attribution of responsibility for the emissions traceable to major carbon producers since 1854 (based on Heede 2014) and the recent attribution of climate impacts — most visibly and viscerally with respect to sea level rise — implicates the fossil fuel industry in causing significant and growing damages to life and property (Frank, 2017). The legal pressure is sure to mount, and we already see the first cases emerge in Germany (RWE; Collyns 2015 *The Guardian*, Schwartz 2016b *New York Times*), and most recently in complaints filed against twenty carbon majors by Marin County, San Mateo County, and Imperial Beach in California in July of this year (Sher Edling Law; see Westervelt 2017, Rosenfeld 2017), and by City of San Francisco and City of Oakland in September (Hagens Berman Law; see *InsideClimate News*).

Individual companies are challenged by investigations of consumer and investor fraud and of human rights violations. New York Attorney General Eric Schneiderman and Massachusetts AG Maura Healey launched an investigation of ExxonMobil in 2015 (Gillis & Krauss, 2015, *New York Times*); the Philippines Commission on Human Rights launched an investigation of human rights violations by 40 major oil, gas, and coal companies (Howard, 2016, *The Guardian*).

More cases are sure to arise seeking compensation or injunctive relief for fossil fuel companies' contribution to climate change and to climate damages. University endowments, investors, and retirement fund managers will continue to challenge the business plans of fossil fuel companies and trade associations for perpetuating high levels of oil, gas, and coal production without sufficient concern for global climate impacts, and to divest from carbon companies, as will lenders, insurers, and underwriters. Investors and lenders are increasingly aware of the risk of potential stranded assets. Policy makers may act to eliminate perverse and market-distorting fossil fuel subsidies and the additional carbon resources tipped from uneconomic to recoverable by virtue of the subsidies (Erickson et al.), and address the enormous misallocation of capital and environmental damages

from carbon subsidies (Coady et al., Nucitelli). Political campaign contributions by fossil fuel companies may be curtailed (unlikely). Industry funding of climate denial and deception campaigns (Brulle, UCS 2015), false advertising (Supran & Oreskes), naming climate science “fake news” (Davenport & Lipton), and the like will flag. Society will fight back (Klein 2014, McKibben 2016).

Whither accountability?

Considerable benefits have accrued to these major carbon producers, and to their individual and institutional investors and state sponsors. Given this, it seems reasonable to argue that they have an ethical obligation to help address climate destabilization (Gardiner 2011, Shue 2017). Moreover, many of these entities — both state- and investor-owned — possess the financial resources and technical capabilities to develop and contribute to climate change mitigation, adaptation, recovery, and remedy for a world in peril.

These companies have helped advance societies and provided power and comfort to civilization. The consequences of emitting increasing amounts of carbon dioxide from the use of fossil fuels were not sufficiently appreciated until, say, 1980 — whereupon it became incumbent on the fossil fuel industry to lead the conversation and help resolve the dilemma of how to cope with climate change. This the industry largely failed to do. The companies have contributed the lion’s share of global CO₂ emissions, and they now have a moral — and perhaps legal — obligation to invest in fossil emission reduction and alternatives, as well as to contribute to adaptation costs, and lead the way in aligning the world economy toward a lower carbon future.

Peter Frumhoff, co-author and UCS director of science and policy, points out that “taxpayers, including those living in vulnerable coastal communities, should not alone have to pay the high costs of these companies’ irresponsible decisions.” (See the excellent op-ed by Frumhoff & Allen.)

Henry Shue, University of Oxford, Dept. of Politics and International Relations, said in his deeply insightful Commentary to our paper that:

“Investor-owned companies have long understood the harm of their products, yet carried out a decades-long campaign to sow doubts about those harms in order to ensure fossil fuels would remain central to global energy production. Companies knowingly violated the most basic moral principle of ‘do no harm,’ and now they must remedy the harm they caused.”

In closing, I can say it no better than the editors of *The Guardian* did in September as Hurricane Irma was barreling toward Florida:

“Fossil-fuel companies should be held accountable for the effects of climate change. Legal warfare has a two-fold aim: to overhaul transgressors’ business models so that they are in line with the global commitment to phase out fossil fuels and limit temperature rises to 1.5°C; and to get them to pay for damages resulting from global warming. Climate litigation is the inevitable result of a failure of two decades of talks. But it is also an important way of reframing the climate crisis as a human rights emergency.”

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## References

- Allen MR, Frame DJ, Huntingford C, Jones CD, Lowe JA, Meinshausen M, Meinshausen N (2009b) Warming caused by cumulative carbon emissions towards the trillionth tonne. *Nature*, **458**:1163-1166
- Arrhenius, Svante (1896) On the influence of carbonic acid in the air upon the temperature of the ground, *Phil. Mag.*, vol. 41:237-.
- Banerjee, Neela, John H Cushman Jr, David Hasemyer, & Lisa Song (2016) CO<sub>2</sub>'s Role in Global Warming Has Been on the Oil Industry's Radar Since the 1960s, *InsideClimate News*, 13 April 2016.
- Banerjee, Neela (2015) Exxon's Oil Industry Peers Knew About Climate Dangers in the 1970s, Too, *InsideClimate News*, 22 December 2015.
- Boden, Tom, Bob Andres, & Gregg Marland (2016) *Global CO<sub>2</sub> Emissions from Fossil-Fuel Burning, Cement Manufacture, and Gas Flaring: 1751-2014*. Carbon Dioxide Information Analysis Center (CDIAC), Oak Ridge National Lab., US Dept of Energy, Oak Ridge; [http://cdiac.ornl.gov/ftp/ndp030/global.1751\\_2014.ems](http://cdiac.ornl.gov/ftp/ndp030/global.1751_2014.ems).
- BP (2016) *Energy Outlook to 2035*, 2016 edition, 98 pp. <https://www.bp.com/content/dam/bp/pdf/energy-economics/energy-outlook-2017/bp-energy-outlook-2017.pdf>
- Brulle, Robert J. (2013) Institutionalizing delay: foundation funding and the creation of U.S. climate change counter-movement organizations, *Climatic Change*, online 21Dec, DOI 10.1007/s10584-013-1018-7
- Carbon Tracker Initiative (2016) *No Rhyme or Reason: Unreasonable projections in a world confronting climate change*, by Rob Schuwerk & Luke Sussams, 66 pp.
- Carbon Tracker Initiative (2014) *Responding to Exxon - A Strategic Perspective*, London, 52 pp.
- Carbon Tracker Initiative (2011) *Unburnable Carbon: are the World's financial markets carrying a carbon bubble?* 36 pp., [www.carbontracker.org](http://www.carbontracker.org)
- Center for International Earth Science Information Network (CIESIN)/Columbia University (2013) *Urban-Rural Population and Land Area Estimates Version 2*. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). <http://sedac.ciesin.columbia.edu/data/set/lecz-urban-rural-population-land-area-estimates-v2>. Accessed 05 October 2017.
- Center for International Environmental Law (2016) *Smoke and Fumes*, Washington, <https://www.smokeandfumes.org>
- Central Intelligence Agency (2016) *The World Factbook 2016*, CIA, Washington, DC, <https://www.cia.gov/library/publications/download/download-2016/index.html>
- Coady, David, Ian W.H. Parry, Louis Sears, & Baoping Shang (2015) *How Large Are Global Energy Subsidies?*, IMF Working Paper #15/105, 18May, 42 p.
- Collyns, Dan (2015) Peruvian farmer demands climate compensation from German company, *The Guardian*, 16 March. <https://www.theguardian.com/environment/2015/mar/16/peruvian-farmer-demands-climate-compensation-from-german-company#img-2>
- Cushman, John (2017) Energy Forecast Sees Global Emissions Growing, Thwarting Paris Climate Accord, *InsideClimate News*, 14 Sep 2017.
- Davenport, Coral & Eric Lipton (2017) How G.O.P. Leaders Came to View Climate Change as Fake Science, *New York Times*, 3 June 2017.
- Ekwerzel, B., J. Boneham, M. W. Dalton, R. Heede, R. J. Mera, M. R. Allen, & P. C. Frumhoff (2017) The rise in global atmospheric CO<sub>2</sub>, surface temperature, and sea level from emissions traced to major carbon producers, *Climatic Change*, vol. 144:579-590. DOI 10.1007/s10584-017-1978-0. <https://link.springer.com/content/pdf/10.1007/s10584-017-1978-0.pdf>
- Emanuel, Kerry (2017) Why it's time to stop calling these hurricane disasters 'natural', *Washington Post*, 19 September.
- Erickson, Peter, Adrian Down, Michael Lazarus, & Doug Koplow (2017) Effect of subsidies to fossil fuel companies on United States crude oil production, *Nature Energy*, online 2 Oct.
- ExxonMobil (2015) *The Outlook for Energy 2016: A View to 2040*, 78 pp. <http://cdn.exxonmobil.com/~/media/global/files/outlook-for-energy/2016/2016-outlook-for-energy.pdf>
- Faria, Pedro, Paul Griffin, & Richard Heede (2016) Aligning an oil and gas company's reserves and future emissions with a 2°C science-based target A preliminary study of an oil and gas major, *International Conference on Fossil Fuel Supply & Climate Change Policy*, Queen's College, Oxford, 26Sep16, 11 slides.
- Frank, Richard M. (2017) Sea level suits are the next frontier in climate change litigation, *Daily Journal*, 28 July.
- Friends of the Earth International (2004) *Exxon's Climate Footprint: the contribution of Exxon-Mobil to climate change since 1882*, 16 pp., London, [foe.co.uk/campaigns/climate/resource/exxonmobil\\_climate\\_footprint.html](http://foe.co.uk/campaigns/climate/resource/exxonmobil_climate_footprint.html) and [https://www.foe.co.uk/sites/default/files/downloads/exxons\\_climate\\_footprint.pdf](https://www.foe.co.uk/sites/default/files/downloads/exxons_climate_footprint.pdf)
- Frumhoff, Peter C. & Myles Allen (2017) Big Oil must pay for climate change. Now we can calculate how much, *The Guardian*, 7 September 2017. [www.theguardian.com/commentisfree/2017/sep/07/big-oil-must-pay-for-climate-change-here-is-how-to-calculate-how-much](http://www.theguardian.com/commentisfree/2017/sep/07/big-oil-must-pay-for-climate-change-here-is-how-to-calculate-how-much)
- Frumhoff, Peter C., Richard Heede, & Naomi Oreskes (2015) The climate responsibilities of industrial carbon producers, *Climatic Change*, vol. 132:157-171; early edition, 23 July, DOI: 10.1007/s10584-015-1472-5.

- Gardiner, Stephen M. (2011) *A Perfect Moral Storm: The Ethical Tragedy of Climate Change*, Oxford University Press, 512 p.
- Germanwatch (2017) *Climate Change Performance Index 2017: A comparison of the 58 top CO<sub>2</sub> emitting nations*, G20 edition. By Jan Burck, Franziska Marten, Christoph Bals, Thea Uhlich, Niklas Höhne, Sofia Gonzales, and Mia Moisio, 36 pp. <https://germanwatch.org/en/13042>
- Gillis, Justin, & Clifford Krauss (2015) Exxon Mobil Investigated for Possible Climate Change Lies by New York Attorney General, *New York Times*, 5 November 2015. <https://www.nytimes.com/2015/11/06/science/exxon-mobil-under-investigation-in-new-york-over-climate-statements.html>
- Griffin, Paul, Richard Heede, & Ian van der Vlugt (2017) *The Carbon Majors Database: Methodology Report 2017*, CDP London & CAI Snowmass, 9 pp.
- Griffin, Paul (2017) *The Carbon Majors Database: CDP Carbon Majors Report 2017*, CDP & CAI, July, 14 pp.
- Guardian, The, Editorial Board (2017) The Guardian view on climate change: see you in court, *The Guardian*, 10 Sept., <https://www.theguardian.com/commentisfree/2017/sep/10/the-guardian-view-on-climate-change-see-you-in-court>
- Heede, Richard (forthcoming) Oil and gas company carbon intensity supply chain performance metrics, Climate Accountability Institute, in progress.
- Heede, Richard, & Naomi Oreskes (2016) Potential emissions of CO<sub>2</sub> and methane from proved reserves of fossil fuels: An alternative analysis, *Global Env. Change*, vol. 36:12-20. [www.sciencedirect.com/science/article/pii/S0959378015300637](http://www.sciencedirect.com/science/article/pii/S0959378015300637).
- Heede, Richard (2014a) Tracing anthropogenic CO<sub>2</sub> and methane emissions to fossil fuel and cement producers 1854-2010, *Climatic Change*, vol. 122(1): 229-241; doi:10.1007/s10584-013-0986-y. URL: <http://link.springer.com/article/10.1007/s10584-013-0986-y?view=classic>
- Heede, Richard (2014b) *Update of Carbon Majors' emissions to 2013 data*, Climate Accountability Institute Press Release, 8 December 2014, Conference of the Parties 20, Lima Peru.
- Heede, Richard (2013) *Carbon Majors: Accounting for carbon and methane emissions 1854-2010 Methods & Results Report*, commissioned by Climate Justice Programme (Sydney) & Greenpeace International (Amsterdam), Climate Mitigation Services, Snowmass, CO, 104 pp. plus pdf worksheets, 674 pp.
- Höhne N, Blum H, Fuglestvedt J et al (2011) Contributions of individual countries' emissions to climate change and their uncertainty. *Climatic Change*, vol. 106:359–391. doi:10.1007/s10584-010-9930-6
- Howard, Emma (2016) Philippines investigates Shell and Exxon over climate change, *The Guardian*, 7 May 2016. <https://www.theguardian.com/sustainable-business/2016/may/07/climate-change-shell-exxon-philippines-fossil-fuel-companies-liability-extreme-weather>
- InsideClimate News (2017) San Francisco, Oakland Sue Oil Giants Over Climate Change, Staff of *InsideClimate News*, 20 September. <https://insideclimatenews.org/news/20092017/san-francisco-oakland-sue-oil-giants-over-climate-change>
- Intergovernmental Panel on Climate Change (2013) *Climate Change 2013: The Physical Science Basis, Summary for Policy Makers*. WG1 Contribution to IPCC AR5, 27 September 2013, 36 pp.
- Johnson, Scott K. (2016) House Science Committee convinced fraud investigations stifle free speech, *Ars Technica*, 15 July.
- Klein, Naomi (2014) *This Changes Everything: Capitalism vs. the Climate*, Simon&Schuster, 576 pp.
- Klinkenborg, Verlyn (2013) Follow the Water, *National Geographic*, November. <http://ngm.nationalgeographic.com/2013/11/coastal-norway/klinkenborg-text>
- Kopp, Robert E., Radley M. Horton, Christopher M. Little, Jerry X. Mitrovica, Michael Oppenheimer, D. J. Rasmussen, Benjamin H. Strauss, & Claudia Tebaldi (2014) Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites, *Earth's Future*, vol. 2:383-406.
- Kulp, Scott, & Benjamin H. Strauss (2016) Global DEM Errors Underpredict Coastal Vulnerability to Sea Level Rise and Flooding, *Frontiers in Earth Science*, April.
- Kusnetz, Nicholas (2017) Exxon Promises to Cut Methane Leaks from U.S. Shale Oil and Gas Operations, *InsideClimate News*, 26 September.
- Leiserowitz, Anthony, Edward Maibach, Connie Roser-Renouf, Seth Rosenthal, & Matthew Cutler (2017) *Climate change in the American mind: May 2017*, Yale University and George Mason University. 48 pp. <http://climatecommunication.yale.edu/wp-content/uploads/2017/07/Climate-Change-American-Mind-May-2017.pdf>
- Mann, Michael (2017) It's a fact: climate change made Hurricane Harvey more deadly, *The Guardian*, 28 August.
- Matthews HD, Gillett NP, Stott PA, Zickfeld K (2009) The proportionality of global warming to cumulative carbon emissions, *Nature*, 459:829-832.
- Magill, Bobby (2017) Half of Modern Global Warming Caused by 90 Companies, New Study Concludes, *Climate Liability News*, 7 September. [www.climate](http://www.climate<liabilitynews.org/2017/09/07/global-warming-fossil-fuel-companies-study-ucs/)
- McKibben, Bill (2016) A World at War: We're under attack from climate change—and our only hope is to mobilize like we did in WWII, *New Republic*, 15 August 2016.
- Millar, Richard J., Zebedee R. Nicholls, Pierre Friedlingstein, Myles R. Allen (2016) A modified impulse-response representation of the global response to carbon dioxide emissions, *Atmospheric Chemistry and Physics Discussions*, 1–20. doi: 10.5194/acp-2016-405

- Mondal, Pinki, & Andrew J. Tatem (2012) Uncertainties in Measuring Populations Potentially Impacted by Sea Level Rise and Coastal Flooding, *PLoS ONE*, vol. 7: e48191. <https://doi.org/10.1371/journal.pone.0048191>
- National Research Council (1979) *Carbon dioxide and climate: a scientific assessment*, National Academies Press, Washington, D.C.
- Nucitelli, Dana (2017) Trump's plan to bail out failing fossil fuels with taxpayer subsidies is perverse, *The Guardian*, 9 October 2017. <https://www.theguardian.com/environment/climate-consensus-97-per-cent/2017/oct/09/trumps-plan-to-bail-out-failing-fossil-fuels-with-taxpayer-subsidies-is-perverse#comments>
- Oreskes, Naomi, & Erik Conway (2010) *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*, Bloomsbury, 355 pp.
- President's Science Advisory Committee (1965) *Restoring the Quality of Our Environment*, Report of the Environmental Pollution Panel. Washington, DC: The White House, November, 317 pp.
- Robinson, Elmer, & R.C. Robbins (1968) *Sources, abundance, and fate of atmospheric pollutants*, Stanford Research Institute, prepared for American Petroleum Institute, Washington DC.
- Rogelj, Joeri, Michel den Elzen, Niklas Höhne, Taryn Fransen, Hanna Fekete, Harald Winkler, Roberto Schaeffer, Fu Sha, Keywan Riahi, & Malte Meinshausen (2016) Paris Agreement climate proposals need a boost to keep warming well below 2 °C, *Nature*, vol. 534:631–639.
- Rosenfeld, Jordan (2017) Bedeviled by Sea Level Rise, 3 Calif. Communities Take on Fossil Fuel Industry, *Climate Liability News*, 22 Sept. <https://www.climateliabilitynews.org/2017/09/22/sea-level-rise-san-mateo-marin-imperial-beach-lawsuit/>
- Royal Dutch Shell (2016) Shell: Energy transitions and portfolio resilience, 38 pp. <http://www.shell.com/sustainability/>
- Schwartz, John (2017) Students, Cities and States Take the Climate Fight to Court, *New York Times*, 10 August 2017.
- Schwartz, John (2016a) Public Campaign Against Exxon Has Roots in a 2012 Meeting, *New York Times*, 23 May 2016.
- Schwartz, John (2016b) In Novel Tactic on Climate Change, Citizens Sue Their Governments, *New York Times*, 10 May. [https://www.nytimes.com/2016/05/11/science/climate-change-citizen-lawsuits.html?\\_r=0](https://www.nytimes.com/2016/05/11/science/climate-change-citizen-lawsuits.html?_r=0)
- Shue, Henry (2017) Responsible for What? Carbon Producer CO<sub>2</sub> Contributions and the Energy Transition, Springboard Commentary on Ekwurzel et al., *Climatic Change*, vol. 144:591–596; online 7Sep; <https://link.springer.com/content/pdf/10.1007/s10584-017-2042-9.pdf>
- Smith, Hon. Lamar (2017) Don't Believe the Hysteria Over Carbon Dioxide, *Daily Signal*, The Heritage Foundation, 24 July; <http://dailysignal.com/2017/07/24/dont-believe-hysteria-carbon-dioxide>
- Starr, Douglas (2016) The carbon accountant: Richard Heede pins much of the responsibility for climate change on just 90 companies, others think that's a copout, *Science*, vol. 353:858–861, 26 August 2016. <http://www.sciencemag.org/news/2016/08/just-90-companies-are-blame-most-climate-change-carbon-accountant-says>
- Supran, Geoffrey, & Naomi Oreskes (2017) What ExxonMobil Didn't Say About Climate Change, *New York Times*, op-ed, 22 August.
- Supran, Geoffrey, & Naomi Oreskes (2017) Assessing ExxonMobil's climate change communications (1977–2014), *Environmental Research Letters*, vol. 12(8), online 23 August.
- Union of Concerned Scientists (2017) *When Rising Seas Hit Home: Hard choices ahead for hundreds of US coastal communities*, Erika Spanger-Siegfried, Kristina Dahl, Astrid Caldas, Shana Udvardy, Rachel Cleetus, Pamela Worth, Nicole Hernandez Hammer. July 2017, 52 pp. [www.ucsusa.org/sites/default/files/attach/2017/07/when-rising-seas-hit-home-full-report.pdf](http://www.ucsusa.org/sites/default/files/attach/2017/07/when-rising-seas-hit-home-full-report.pdf)
- Union of Concerned Scientists (2015) *The Climate Deception Dossiers: Internal Fossil Fuel Industry Memos Reveal Decades of Corporate Disinformation*, July, 45 pp., [www.ucsusa.org/decadesofdeception](http://www.ucsusa.org/decadesofdeception).
- Union of Concerned Scientists & Climate Accountability Institute (2012) *Establishing Accountability for Climate Change Damages: Lessons from Tobacco Control*, Summary of the Workshop on Climate Accountability, Public Opinion, and Legal Strategies, Scripps Institution of Oceanography, La Jolla, CA, 14–15 June 2012, UCS & CAI, 36 pp. <http://climateaccountability.org/pdf/Climate Accountability Rpt Oct12.pdf>
- United Nations (1992) *United Nations Framework Convention on Climate Change*, Articles 3 and 2. New York. [unfccc.int/resource/docs/convkp/conveng.pdf](http://unfccc.int/resource/docs/convkp/conveng.pdf)
- Wei T, Yang S, Moore JC, Shi P, Cui X, Duan Q, Xu B, Dai Y, Yuan W, Wei X, Yang Z, Wen T, Teng F, Gao Y, Chou J, Yan X, Wei Z, Guo Y, Jiang Y, Gao X, Wang K, Zheng X, Ren F, Lv S, Yu Y, Liu B, Luo Y, Li W, Ji D, Feng J, Wu Q, Cheng H, He J, Fu C, Ye D, Xu G, Dong W (2012) Developed and developing world responsibilities for historical climate change and CO<sub>2</sub> mitigation. *Proc. Natl. Acad. Sciences*, vol. 109:12911–12915.
- Westervelt, Amy (2017) California Communities Sue to Hold Fossil Fuel Companies Responsible for Sea Level Rise, *Climate Liability News*, 21 July 2017. [www.climateliabilitynews.org/2017/07/21/california-communities-sue-to-hold-fossil-fuel-companies-responsible-for-sea-level-rise/](https://www.climateliabilitynews.org/2017/07/21/california-communities-sue-to-hold-fossil-fuel-companies-responsible-for-sea-level-rise/)
- World Resources Institute & World Business Council for Sustainable Development (2004) *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard*, Revised Edition, March, 112 pp.