The Arc of the Carbon Majors Work Bends Toward Fossil Fuel Company Accountability

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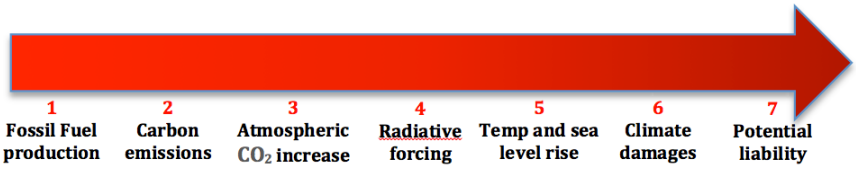
'Qui peut et n'empesche, pesche' — *He who can but does not prevent, sins.*

Preamble.

The evidence is now overwhelming that, for more than half a century, fossil fuel companies continued to produce and market their products despite stark warnings that doing so would harm their customers, inflict catastrophic losses on communities across the planet, and unravel the web of life upon which humanity depends. Rather than working to avoid or minimize these harms, fossil fuel companies even today are doubling down on increasing production and sale of their dangerous products, prioritizing corporate profit over the health, safety, and human rights of humanity. Doing so is not just morally reprehensible, it is legally culpable.

This essay traces the origin and evolution of the Carbon Majors project, and measures our progress toward the objective of transforming the world's carbon-based energy toward zero emissions, and, if required, negative emissions, in order to restore climate calm later in the millennium.

I will track our progress and accomplishments against the arc of our work, all based on holding fossil fuel *companies* accountable, starting from documenting their fossil fuel production, estimating operational and product-use emissions, modeling climate change and climate impacts, quantifying damages and reparations, and (perhaps) holding the companies legally liable.



Acknowledgements

As in all science, progress is built on the work of others, sometimes by tearing down the old paradigm, at other times replacing it with a new concept. For me, the old paradigm was that embraced by the UNFCCC regarding shared responsibilities and burdens, which runs through the noble intent and the process of the Conference of the Parties for thirty years without sufficient progress to meaningfully avoid "dangerous anthropogenic interference with the climate system."[1] The carbon fuel industries have fought in local, state, national, and international fora against sensible, timely, and effective policies to reduce fossil fuel production, use, and emissions that align with the best scientific knowledge.

This new paradigm of corporate responsibility was shaped by many friends and colleagues over the years. Most of all by Peter Roderick (formerly of Climate Justice Program, London), Naomi Oreskes (Harvard), Peter Frumhoff (UCS and Harvard), Carroll Muffett (FILE), and Sally Ranney (Global Choices), but also my early supporters and funders: Kristin Casper (Greenpeace), Steve Leonard and Keely Boom (CJP), Richard Mott (Wallace Global Funds), Michael Northrop (Rockefeller Brothers Fund), Lee Wasserman (Rockefeller Family Fund) and individual donors. Many colleagues and superb analysts have supported and extended the Carbon Majors work from their own perspectives: Myles Allen (Oxford), Geoffrey Supran (Miami), Ben Franta (Oxford), scientific collaborators too numerous to list here (see citations in text), and many others who have used the Carbon Majors data for new and exciting projects. Lawyers, attorneys general, and non-profit attorneys have also adopted the Carbon Majors rationale and results to press litigation against fossil fuel producers.

To all of you a hearty thanks for our joint vision of mitigating the climate harms that threaten our beautiful planet and its inhabitants. We deserve a chance to endure.

[1] *United Nations Framework Convention on Climate Change*, 1992. https://unfccc.int/resource/docs/convkp/conveng.pdf

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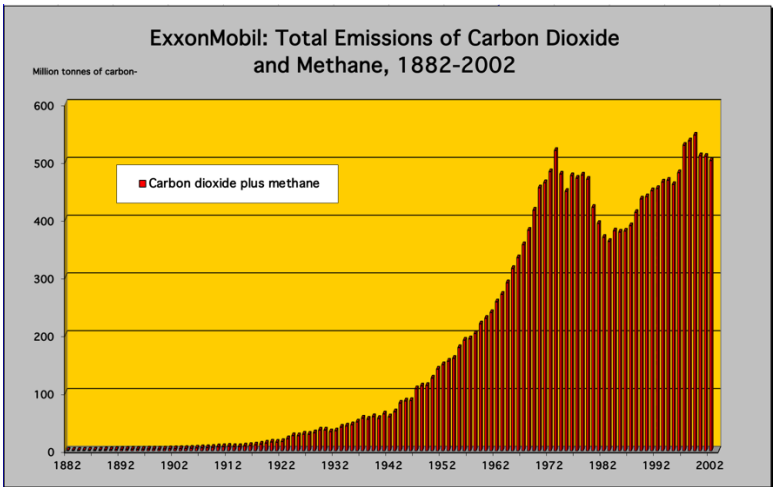
Richard Heede

13 October 2026

"*The arc of history is long but it bends towards justice*," Barack Obama[2] 2007.

My first foray into attributing emissions to a large oil and gas producer was a project commissioned by the London-based Climate Justice Programme, in which we focused on the emissions attributable to ExxonMobil and its predecessors (e.g., Standard Oil Company and its successors Standard Oil of New York [Socony] later renamed Mobil, and Standard Oil of New Jersey [SONJ] later renamed Exxon, from 1882 to 2002; they merged in 1999). The emissions attributed to the company included emissions from sold products such as kerosene, gasoline, diesel, home heating oil, and (for several years) its coal production as well as estimated scope 1 operational emissions from venting and flaring and company energy use. The emissions attributed to this company totaled 21.5 billion tonnes CO_2e ($GtCO_2e$).[3] Figure 1 shows the company's operational and product emissions over time.

Figure 1. ExxonMobil (and predecessors) attributed emissions 1882-2002.



Source: Heede 2003.

Our inventory was the basis for an early pioneering climate model of a fossil fuel producer's impact on the rise of atmospheric CO_2, surface temperatures, and sea level.[4] The attributed historical emissions provided the foundation for Friends of the Earth International's *Exxon's Climate Footprint: the contribution of ExxonMobil to climate change since 1882,* which urged ExxonMobil to "assess its potential liability for the current and future damage caused by climate change and set aside a segregated fund to meet claims that may, in the future, be made against it."[5]

That prescient advice remains valid today, as numerous lawsuits against major carbon producers have been filed in ~36 jurisdictions across the U.S. and dozens more worldwide.[6]

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[2] From MLK, 1968 sermon: "*We shall overcome because the arc of a moral universe is long, but it bends toward justice*."

[3] Heede, Richard (2003) *ExxonMobil Corporation: Emissions Inventory 1882-2002: Methods & Results*, Climate Mitigation Services, Snowmass, Colorado, USA, December, for Friends of the Earth Trust Ltd, London; 30 pp. http://www.climatemitigation.com/climate-mitigation-services-publications.html

[4] Salinger, Jim, & Greg Bodeker (2003) *Assessing the Effects of CO_2, CH_4, and N_2O Emissions on Atmospheric Concentrations, Changes in Radiative Forcing, Changes in Global Mean Surface Temperature, and Changes in Sea Level: A Case Study*, National Institute of Water & Atmospheric Research Ltd, Auckland, New Zealand, December, for Friends of the Earth Trust Ltd, 49 p.

[5] Friends of the Earth International (2004) *Exxon's Climate Footprint: the contribution of Exxon-Mobil to climate change since 1882*, London, 16 pp, January. http://sustainabilitynow.com/Docs/exxons_climate_footprint.pdf

[6] Sabin Center for Climate Change Law, Columbia University: https://climate.law.columbia.edu/content/resources, and climatecasechart.com

Climate Justice then commissioned me to broaden the scope to include a number of other fossil fuel producers' historical production and emissions in order to establish legal traction and credibility by scientifically and objectively document the attributable corporate emissions for a larger proportion of all fossil fuel emissions globally than ExxonMobil's ~3.5% share of such emissions since 1751.[7]

This daunting task captured my imagination of the importance of providing the evidentiary basis required to hold fossil fuel companies accountable for changing the climate and the foreseeable (but ignored) global havoc brought by their emissions.

My job was simply to document each company's history of fossil fuel production and establish a credible, peer-reviewed methodology for attributing emissions to the "Carbon Majors" and their global customers using their fuels as intended.

The science was well advanced by the 2000s — proof of climate change is "unequivocal" and "very likely" due to human GHG emissions[8] — and fossil fuel producers had no excuse but to support domestic and international efforts to curb emissions. This they did not do; instead, they equivocated, shifting blame to consumers (BP ads asked consumers "what is your carbon footprint?") and to governments in an effort to delay action to reduce fossil fuel production and to perpetuate $-trillion profits abetted by $-trillion subsidies.[9,10]

In 2005, with crucial funding from CJP and Greenpeace International, I started on the years-long process of broadening the scope and historical depth needed for a comprehensive Carbon Majors database. I set a threshold of fossil fuel extraction at 8 million tonnes of carbon (MtC) in order to have a manageable number of companies. I assembled an initial list of prospective oil, gas, and coal producers from every carbon region around the world, wrote up a detailed research plan and an emission estimation protocol — peer-reviewed by Greenpeace International's Science Unit analysts and by Kornelis Blok of Ecofys in Utrecht — and fine-tuned the methodology. I wanted an unassailable methodology and the most credible results based on publicly available data I could secure, which also required documenting companies' published production data, and applying robust emission factors, in order to provide conservative emission estimates.

Then the real work began. First, I had to acquire the annual reports and SEC filings needed to base the results on corporate records and publications. I visited business libraries, online sources, downloaded SEC digital filings, and scoured dusty library collections around the world, often with the help of colleagues and graduate students at key universities. Second, I hired an assistant to help me enter the production data on templates for each company, which converted daily production into annual production for oil and natural gas liquids (and oil sands or bitumen, for some companies), coal by rank of coal, and so on. Over several years

[7] Carbon Majors contribution of CO_2 and energy-related methane is compared to global fossil fuel emissions and cement, e.g., from the CDIAC database 1751-fwd, now merged with Global Carbon Project: https://www.globalcarbonproject.org

[8] IPCC (2007) *Fourth Assessment Report: Summary for Policymakers*.

[9] Verbruggen, Aviel (2022) The geopolitics of trillion US$ oil & gas rents, International, *Journal of Sustainable Energy Planning and Management*, vol. 36:3–10.

[10] International Monetary Fund (2023) *IMF Fossil Fuel Subsidies Data: 2023 Update*, by Simon Black, Antung A. Liu, Ian W.H. Parry, & Nate Vernon, 24 August. https://www.imf.org/en/Publications/WP/Issues/2023/08/22/IMF-Fossil-Fuel-Subsidies-Data-2023-Update-537281

we built a database covering ninety entities from as early as 1854 to the present, accounted for mergers and acquisitions (which are attributed to the extant entity), and populating a set of ~200 worksheets all dynamically linked to summary sheets that convert production into estimated scope 1 operational emissions and scope 3 product-related emissions.

The pioneering aspect of the work was to quantify emissions from the production, processing, transportation, and consumption of carbon fuels and to attribute the full supply chain of emissions to the carbon producers, soon to be known as the "Carbon Majors." Readers interested in the methodology can consult my *Methods & Results Report*.[11]

The Carbon Majors project is a scientific investigation firmly based on objective analysis of company-reported fossil fuel production that applies a robust and peer-reviewed methodology in order to fairly and reasonably quantify emissions of carbon dioxide and methane attributable to each company over its history.

Creating, commissioning, and completing this database took several years from the mid-2000s onwards, continually searching for historical documents, expanding the coverage, calculating operational emissions, applying well-documented emission factors, and writing up the *Methods & Results* report. In 2011, when the work was nearing fruition, I met Naomi Oreskes, then teaching at UCSD La Jolla, at a climate event in Aspen. She and Erik Conway had just published *Merchants of Doubt* and she was intrigued by the application of the work to holding companies accountable. We agreed that creating a non-profit organization would advance the work and allow me to seek funding from charitable foundations. The Climate Accountability Institute was founded in September 2011, with seed funding from Greg Erwin in Aspen.

Naomi introduced me to Peter Frumhoff, then Dir. Science & Policy at Union of Concerned Scientists, at the Memorial Stephen Schneider "Now It's Up to Us" Symposium in Boulder that August.[12] I had done my thesis work at the National Center for Atmospheric Research in the 1980s, where Steve had been a mentor to me.[13] Meeting Peter was a watershed, and I owe a lot to both Naomi and Peter for seeing the value in my Carbon Majors work.

> *"In my view, staying out of the fray is not taking the `high ground'; it is just passing the buck."* — SHS.

Under Peter's and Naomi's lead the Union of Concerned Scientists (UCS), jointly with CAI and UC-SD, organized a workshop on "Establishing Accountability for Climate Change Damages: Lessons from Tobacco Control" in mid-2012 in La Jolla at which I presented my preliminary results. Scientists, historians, lawyers, and communications experts from both the tobacco and climate perspectives compared notes and discussed the likely evolution of climate litigation against the fossil fuel industry and how to communicate to the public. Industry critics would later call this a cabal and the

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[11] Heede, Richard (2014b) *Carbon Majors: Accounting for carbon and methane emissions 1854-2010: Methods & Results Report*, commissioned by Climate Justice Programme & Greenpeace International, Climate Mitigation Services, Snowmass, CO, 104 pp. plus pdf worksheets, 674 pp.

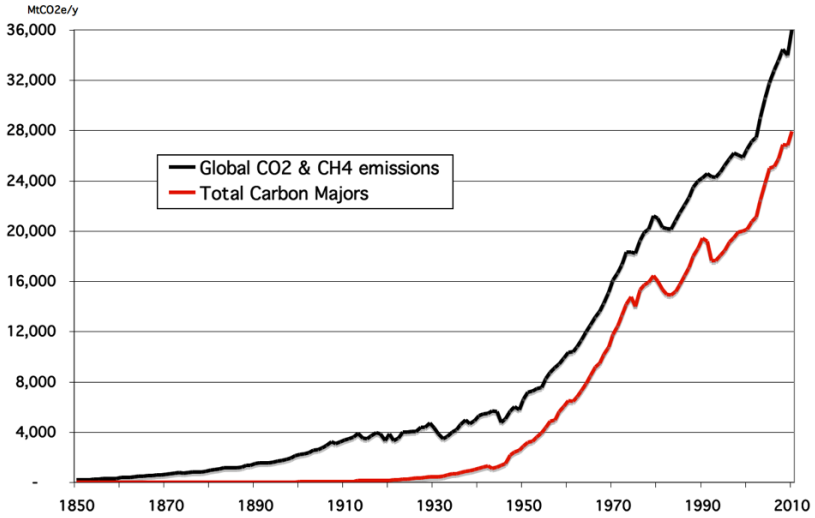
[12] Stephen H. Schneider Symposium: *Climate Change: From Science to Policy*, NCAR, Boulder, 24-27 August 2011. https://stephenschneider.stanford.edu/Symposium/SHS_symposium.html

[13] Heede, Richard (1983) *A World Geography of Recoverable Carbon Resources in the Context of Possible Climate Change*, NCAR Cooperative Thesis CT-72, National Center for Atmospheric Research & University of Colorado, Boulder, CO, 135 pp.

secret result a playbook for litigation against oil and gas companies. Nothing was secret, and we published in the open.[14]

It became clear that in order to have the Carbon Majors work, so painstakingly accumulated, gain credibility in court and in public opinion that it required publication in a science journal and pass the critical eye of peer-review scientists. This would be my first professional paper, and, as is typical, it took numerous drafts and several rejections by editors, but finally it was accepted by the leading journal *Climatic Change* (founded by Steve Schneider). The paper was published online in November 2013.[15] It caused a firestorm of media exposure for the notion that extant fossil fuel companies could be held to account, that their collective contribution amounted to 63% of all fossil fuel emissions since 1751, and that their CEOs, who could all fit in a couple of Greyhound buses, had presided over the climate crisis without taking meaningful action to curb the harms.[16] Not everyone got the message, and the satirical *Onion* instead put the blame on consumers, mirroring the oil & gas companies' propaganda today.[17] I haven't gotten a Christmas card from Chevron since.

Figure 2. Carbon Majors 1850-2010



Heede 2014. "Global CO_2 & CH_4 emissions" refers to global fossil fuel and cement, not overall GHG.

The climate responsibilities of carbon producers

Peter, Naomi, and I collaborated on a paper exploring the climate responsibilities of carbon producers (as opposed the normative responsibilities and burden-sharing of nations' "common but differentiated responsibilities and respective capabilities"), concluding that carbon producers bear substantial responsibility for climate change. We set out objectives for investor-owned companies, including "unequivocally communicate to the public, shareholders, and policymakers the climate risks resulting from continued use of their products," disavow contrary claims, and accelerate their transition to low-carbon energy production.[18]

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[14] Union of Concerned Scientists & Climate Accountability Institute (2012) *Establishing Accountability for Climate Change Damages: Lessons from Tobacco Control, Workshop on Climate Accountability, Public Opinion, and Legal Strategies*, Scripps Institution of Oceanography, La Jolla, CA, 14-15 June 2012, 36 pp. https://www.ucsusa.org/sites/default/files/attach/2016/04/establishing-accountability-climate-change-damages-lessons-tobacco-control.pdf

[15] Heede, Richard (2014) Tracing anthropogenic CO_2 and methane emissions to fossil fuel and cement producers 1854-2010, *Climatic Change*, vol. 122(1): 229-241; http://link.springer.com/article/10.1007/s10584-013-0986-y?view=classic

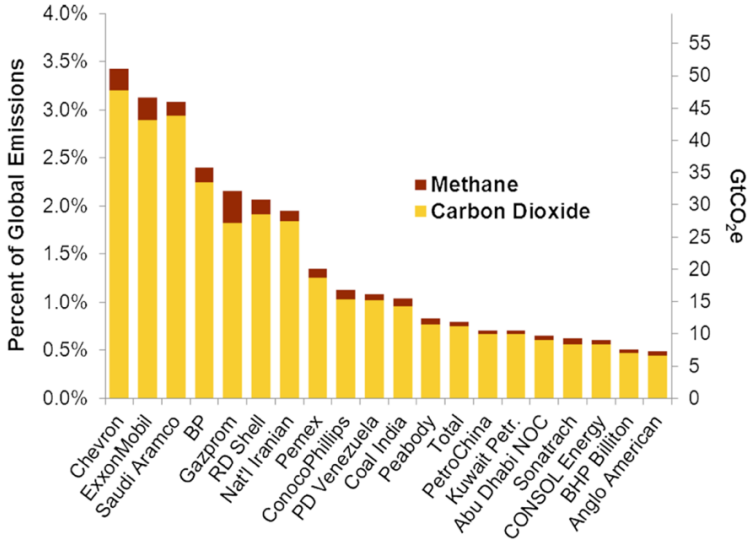
[16] Goldenberg, Suzanne (2013a) Just 90 companies caused two-thirds of man-made global warming emissions, *The Guardian*, 20 November. https://www.theguardian.com/environment/2013/nov/20/90-companies-man-made-global-warming-emissions-climate-change >> *Interactive:* https://www.theguardian.com/environment/interactive/2013/nov/20/which-fossil-fuel-companies-responsible-climate-change-interactive

[17] *The Onion* (2013) New Report Finds Climate Change Caused By 7 Billion Key Individuals, 22 Nov.

[18] Frumhoff, Peter C., Richard Heede, & Naomi Oreskes (2015) The climate responsibilities of industrial carbon producers, *Climatic Change*, vol. 132:157-171; online 3 July. https://link.springer.com/article/10.1007/s10584-015-1472-5

Naomi and Peter were crucial allies in leveraging my work into advocacy for climate responsibility, as well as using the database in attributing climate impacts (such as surface temperature response, sea level rise, and ocean acidification) in climate modeling. Later, I would apply the Carbon Majors dataset to attribute damages and quantifying the financial burdens of climate remediation. Independently, and over several years, the body of published work and the Carbon Majors source attribution database came to the attention of attorneys who were developing legal theories of holding fossil fuel companies accountable for climate impact — such as extreme weather, wildfires, floods, heatwaves, and infrastructure losses — whose societal costs would accelerate.

Figure 3. Twenty major carbon producers' cumulative emissions 1854-2010



Frumhoff et al. 2015, Fig 2. Cumulative emissions 1854-2010 traced to historic fossil fuel production by the largest investor- and state-owned oil, gas, & coal producers, in percent of global industrial CO_2 & methane emissions since 1751

The climate impacts of carbon producers' proven reserves

In 2016 Naomi and I assessed the potential emissions inherent in company-declared proved recoverable reserves of oil, gas, and coal and compared those carbon quantities to what (at that time) remained in the global 2°C carbon budget (at that time ~275 GtC, at 66% probability).[19] We found that the Carbon Majors alone held reserves equivalent to 440 GtC, substantially more than should be consumed, even if accounting for anticipated non-energy uses (for petrochemicals, road oil, etc.). The temperature threshold has for good reasons been reset at 1.5°C, per the Paris Agreement (2015). Clearly, as Carbon Tracker and others have documented, reserves far exceed what can "safely" be emitted. Bear in mind that not only has the remaining carbon budget shrunk but reserves have, by and large, *not* decreased: reserve additions typically cover annual production (companies vary); global oil and gas reserves are up (doubling since ~1988), and coal reserves have declined. A recent estimate is that the RCB under 1.5°C is 68 GtC (50% probability).[20]

The Congressional subpoena

While in London in May 2016 to work with CDP staff, I and other organizations received a subpoena from the U.S. House Committee on Science, Space, & Technology — BAM!!! — kindly requesting that I turn over all records regarding my participation in the 2012 La Jolla workshop and any and all communications between myself and state attorneys general, and documents and communications between CAI and the Institute's charitable funders, colleagues (at UCS, Greenpeace, 350, Climate

[19] Heede, Richard, & Naomi Oreskes (2016) Potential emissions of CO_2 and methane from proved reserves of fossil fuels: An alternative analysis, *Global Env'l Change*, vol. 36:12-20. www.sciencedirect.com/science/article/pii/S0959378015300637

[20] Lamboll, Robin D., R. J. Zebedee Nicholls, Christopher J. Smith, Jarmo S. Kikstra, Edward Byers, & Joeri Rogelj (2023) Assessing the size and uncertainty of remaining carbon budgets, *Nature Climate Change*, vol. 13:1360–1367.

Reality Project), climate lawyers, and so on. Chairman Lamar Smith (R-TX), well known for his support of the oil industry and his climate denial leanings, accused us of a coordinated attempt to "deprive companies, nonprofit organizations, and scientists of their First Amendment Rights and ability to fund and conduct scientific research free from intimidation and threats of prosecution."

Since Climate Accountability Institute had not received any Federal funding or contracts, the Science Committee lacked jurisdiction over my work. Peacefully assembling and discussing the matter of climate change with like-minded individuals and petitioning the government is the very essence of protected speech under the First Amendment. I and the other individuals and organizations respectfully declined to provide the requested materials. I offered to instead meet with the Science Committee to present my work on attributing emissions to fossil fuel companies, including Texas-based ExxonMobil. After several months of new subpoenas from the Committee, and responses by our pro bono attorneys, who have my gratitude, the Committee failed to move the matter to a vote.

It was an intimidation tactic, pure and simple, and the reek of the House Un-American Activities Committee gave me chills. Lamar Smith retired in 2019.

Figure 4. Letterhead of the House Science Committee subpoena, 18 May 2016.

Congress of the United States
House of Representatives
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515–6301
(202) 225–6371
www.science.house.gov

May 18, 2016

Mr. Richard Heede
Board of Directors
Climate Accountability Institute

The climate impacts of major carbon producers

My original 2014 *Climatic Change* paper had unleashed some very interesting work in collaboration with UCS scientists and others based on the Carbon Majors database. Brenda Ekwurzel and her team ran a climate model, with input data on emissions traced to fossil fuel companies, that estimated the change in atmospheric CO_2 concentration, surface temperature response, and sea level rise (SLR) attributable to each Carbon Major entity over two periods of time: 1880-1980, and 1980-2010.[21] We found that emissions attributed to the ninety Carbon Majors contributed 57% of atmospheric CO_2 concentration (+99 ppm 1880-1980), ~42-50% of the surface temperature increase (+0.85 °C 1880-1980), and ~26-32% of global sea level rise (+18 cm 1880-1980). See Figure 5.

> *It would take Niagara Falls flowing for more than eighteen years to equal the amount of sea level rise brought by these six energy producers since 1980 (Chevron, ExxonMobil, Shell, Peabody, ConocoPhillips, and BP).* — Union of Concerned Scientists, 2017.

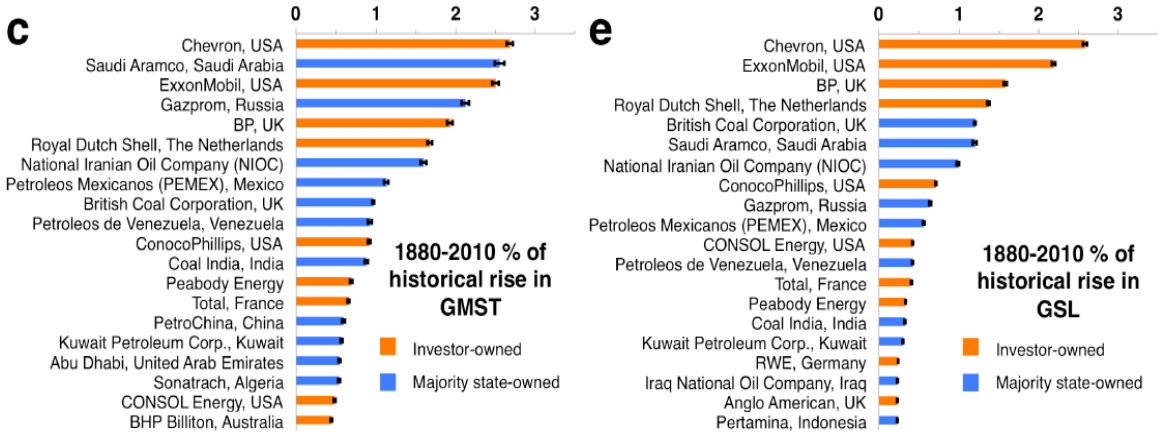
From this work I roughly estimated the amount of land loss attributable to each company's SLR rise: taking attributed SLR from 1980-2010 emissions alone, Saudi Aramco is the largest contributor (37 $GtCO_2e$, 3.23 ppm, 0.0174 °C, and 1.43 mm of sea level rise, and thus an estimated global land loss of 602 km^2. Exxon's contribution (#3: 27 $GtCO_2e$, 2.16 ppm, 0.0171 °C, and 1.14 mm of SLR, and 482 km^2 of global land submergence.[22] This land loss occurs along the majority of the world's coastlines,

[21] Ekwurzel, B., J. Boneham, M. W. Dalton, R. Heede, R. J. Mera, M. R. Allen, & P. C. Frumhoff (2017) The rise in global atmospheric CO_2, surface temperature, and sea level from emissions traced to major carbon producers, *Climatic Change*, vol. 144:579-590; https://link.springer.com/article/10.1007/s10584-017-1978-0

[22] Heede, Richard (2017) *Carbon producers' tar pit: dinosaurs beware: The path to accountability of fossil fuel producers for climate change & climate damages*, Institute for New Economic Thinking: Plenary Conference Edinburgh, 23 October, 16 p. https://www.ineteconomics.org/research/research-papers/carbon-producers-tar-pit-dinosaurs-beware

~2.5 million km in length, but incrementally leads to inundation of critical infrastructure, such as powerplants, airports, harbors, and residential areas. The planning for "managed retreat" goes on.

Figure 5. Temperature and sea level rise attributed to leading Carbon Majors



Ekwurzel et al. (2017), Figure 2c and 2e.

Following the Ekwurzel paper we investigated the impact of Carbon Majors' fossil fuel production and attributed emissions on ocean acidification, finding that the 88 largest carbon producers from 1880 to 2015 have contributed ~55% of the historical decline in surface ocean pH.[23] We suggested that impacts on fisheries, livelihoods, income, and marine ecosystems can inform societal debate on risks, losses, and damages.

The Carbon Majors database update with CDP

I had met Pedro Faria (then CDP's Strategic Advisor) at COP-20 in Lima in 2014, where UCS and I were presenting our results at side events organized by UCS. Pedro and I agreed to collaborate on an update of the Carbon Majors database. The wheels were turning on getting institutional traction and media attention on the responsibilities of fossil fuel companies to address their climate impacts.

The CDP report was released in July 2017.[24]

CAI released an update on Carbon Majors in November 2019 along with features in *The Guardian*.[25]

White Knights, or Horsemen of the Apocalypse?

Dario Kenner (now at University of Sussex) had published an interesting book on climate and wealth and we agreed to research corporate and executive financial incentives within oil and gas companies that were contrary to the global need to reduce emissions.[26] We concluded that the public commitments of leading oil and gas companies to reduce emissions in line with the science are not credible, and that industry would need to be compelled, by government regulation, continued pressure from investors, or other societal or legal means. Neither company executives nor their directors have the financial incentives to reduce exploration for and production of existing and new reserves of fossil fuels. The paper also quantifies compensation packages of executives and

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[23] Licker, Rachel, Brenda Ekwurzel, Scott C. Doney, Sarah R. Cooley, Ivan D. Lima, Richard Heede, & Peter C. Frumhoff (2019) Attributing ocean acidification to major carbon producers, *Environmental Research Letters,* vol. 14(12); online: https://iopscience.iop.org/article/10.1088/1748-9326/ab5abc

[24] Griffin, Paul (2017) *The Carbon Majors Database: CDP Carbon Majors Report 2017*, CDP & CAI, July, 15 pp. https://cdn.cdp.net/cdp-production/cms/reports/documents/000/002/327/original/Carbon-Majors-Report-2017.pdf

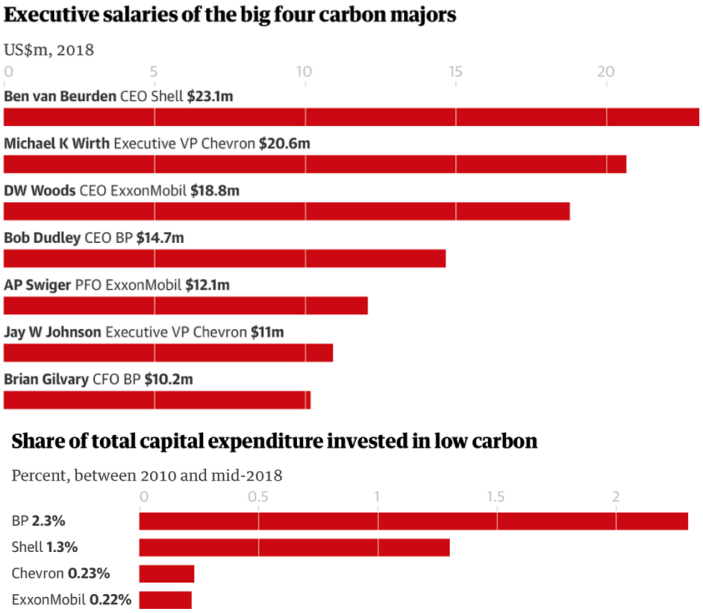
[25] Taylor, Matthew, & Jonathan Watts (2019) Revealed: the 20 firms behind a third of all carbon emissions, *The Guardian*, 9 October. https://www.theguardian.com/environment/2019/oct/09/revealed-20-firms-third-carbon-emissions.

Heede, Richard (2019) It's time to rein in the fossil fuel giants before their greed chokes the planet, *The Guardian*, 9 October. https://www.theguardian.com/commentisfree/2019/oct/09/fossil-fuel-giants-greed-carbon-emissions

[26] Kenner, Dario (2019) *Carbon Inequality: The Role of the Richest in Climate Change*, Routledge, 138 pp.

directors of BP, Chevron, ExxonMobil, and Shell, as well as the emissions associated with executives' shareholdings: leading the list: John Watson, then-CEO of Chevron: 0.60 million tonnes CO_2e.[27],[28]

Figure 6. Executive salaries of leading oil and gas companies



Source: Watts, *The Guardian*, 2021.

The Philippine Commission on Human Rights: National Inquiry on Climate Change

The Commission on Human Rights of the Philippines had launched the *National Inquiry on Climate Change* on the role of the Carbon Majors in violating the human rights of Philippine citizens with respect to a safe, clean, healthy, and sustainable environment. The inquiry report (announced in 2015) was published in 2022 and found that 47 Carbon Majors engaged in "willful obfuscation" of climate science and actively blocked a transition to a low-carbon economy. I had, along with several other local and international climate scientists and lawyers, testified to the Commission in Quezon City in 2018 (and, informally, at COP-21 in Paris). CAI's board member Carroll Muffett, who also testified before the Commission, observed that "with respect to the profound and pervasive human rights impacts of climate change are compelling, carefully documented, and too often tragic."

> *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.*
>
> — Carroll Muffett, CIEL[29]

Time to Pay the Piper

The issue of who should pay for climate damages looms large in current initiatives to fund the Green Climate Fund, Loss & Damage mechanism under the UNFCCC, and state or regional efforts to fund remedial or burden-sharing arrangements. I have taken the approach that fossil fuel producers have a moral obligation to pay for the damages they caused and exacerbated (through willful delays of

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[27] Kenner, Dario, & Richard Heede (2021) White Knights, or Horsemen of the Apocalypse? Prospects for Big Oil to align emissions with a 1.5°C pathway, *Energy Research & Social Science*, vol. 79: art. no. 102049. https://www.sciencedirect.com/science/article/pii/S2214629621001420

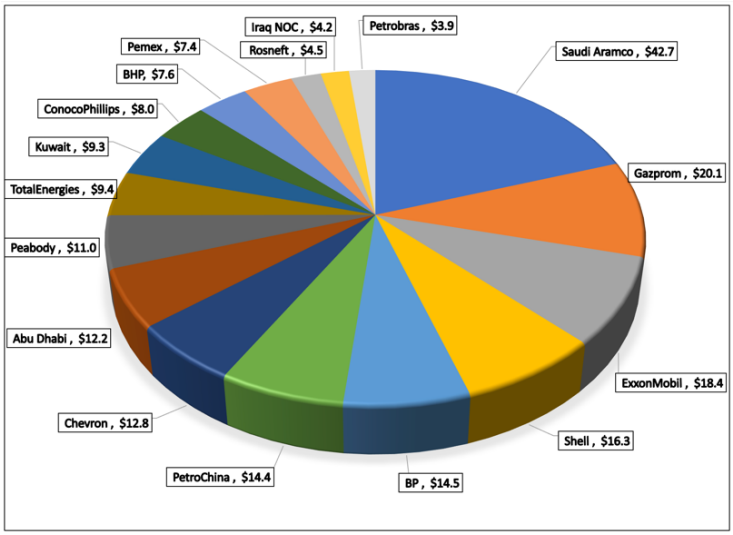
[28] Watts, Jonathan (2021) Oil firm bosses' pay 'incentivises them to undermine climate action' *The Guardian*, 15 April. https://www.theguardian.com/environment/2021/apr/15/oil-firm-ceos-pay-is-an-incentive-to-resist-climate-action-study-finds

[29] Quoted in CIEL Press Release (2017) *Oil, gas, and coal producers' contribution to rise of atmospheric CO_2, surface temperature, and sea level is modeled*, 7 September. https://www.ciel.org/news/oil-gas-coal-producers-contribution-rise-atmospheric-co2-surface-temperature-sea-level-modeled/

actions to curb emissions). In that vein, and underscored by Barbados Prime Minister Mia Mottley at COP-27 declaring that we need to "Let them pay for climate damages," meaning oil, gas, and coal companies, rather than leaving the burden to States, their taxpayers, and developing nations.[30]

> *We believe the non-state actors, the stakeholders and the oil and gas companies and those that facilitate them, need to be brought into convocation between now and COP28. How do companies that make 200 billion in profits in the last three months not expect to contribute at least 10 cents in every dollar in profit into a loss and damage fund?* — Mia Mottley, 2023.[31]

Marco Grasso, who I had met years earlier at the International Conference on Fossil Fuel Supply & Climate Change Policy at Oxford, approached me to suggest we collaborate on a paper on the moral obligation by Carbon Majors to pay climate reparations and to quantify, based on each company's contribution to emissions, climate impacts, and climate damages, a fair attribution of proportional damages. We used an economists' consensus estimate of loss of GDP to 2075 (of a 3°C pathway) and a GDP loss ($2019) of $29.8 trillion in 2075. Drawing a 3% per annum growth curve from 2019 to 2075 and adding GDP loss to 2050 yielded cumulative loss of $99 trillion, then accounted for non-energy gases and land use and forestry emissions (~29.6%) thus $69 billion to fossil fuel use, of which we attributed equal one-third responsibility to 1.) policy makers, 2.) consumers, and 3.) fossil fuel producers ($23 trillion to each primary agent of climate damages), of which $13 trillion of all Carbon Majors, of which the 20 largest contributors to atmospheric emissions accounted for $5.4 trillion. Annual reparations (chart).[32]



An alternative analysis by Carl Schleussner and colleagues at Climate Analytics and IIASA, using the Social Cost of Carbon Dioxide (SCCO2) of $185/t$CO_2$, also adopted the approach Grasso and I proposed to equally share estimated damages among policy-makers, consumers, and fossil fuel companies, concluded that contributions from "fossil fuel wealth" are needed to finance Loss & Damage. This work is based on emissions attributed to twenty-five leading Carbon Majors from 1985 to 2018, calculating that the combined damages amounted to ~$20 trillion, whereas as the same companies profited ~$30 trillion over the same period. We concluded that Carbon Majors, going forward, could well afford to substantially help finance the Loss and Damage Fund.[33]

Evaluating fossil fuel companies' alignment for 1.5°C pathways

I met Saphira Rekker (University of Queensland) at CDP/ACT workshop on assessing oil and gas industry low-carbon transition in Paris in 2019 (we were on the Technical Working Group, along with NGO and progressive oil company representatives). She had written a paper comparing fossil

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[30] Farand, Chloé, & Megan Darby (2022) COP27 bulletin: Loss & damage 'our daily nightmare' *Climate Home News*, 8 Nov. https://www.climatechangenews.com/2022/11/08/cop27-bulletin-loss-and-damage-our-daily-nightmare/

[31] Mia Mottley, at COP-27 World Leaders Summit, https://www.youtube.com/watch?v=5J0egwAfO0w&themeRefresh=1

[32] Grasso, Marco, & Richard Heede (2023) Time to pay the piper: fossil fuel companies' reparations for climate damages, *One Earth*, online 19 May. https://www.cell.com/one-earth/fulltext/S2590-3322(23)00198-7

[33] Schleussner, Carl-Friedrich, Marina Andrijevic, Jarmo Kikstra, Richard Heede, Joeri Rogelj, Holly Simpkin, and Sylvia Schmidt (2023) *Carbon majors' trillion-dollar damages: The case for contributions from fossil wealth to loss and damage finance*, Climate Analytics, Berlin, 36 pp. https://climateanalytics.org/publications/carbon-majors-trillion-dollar-damages

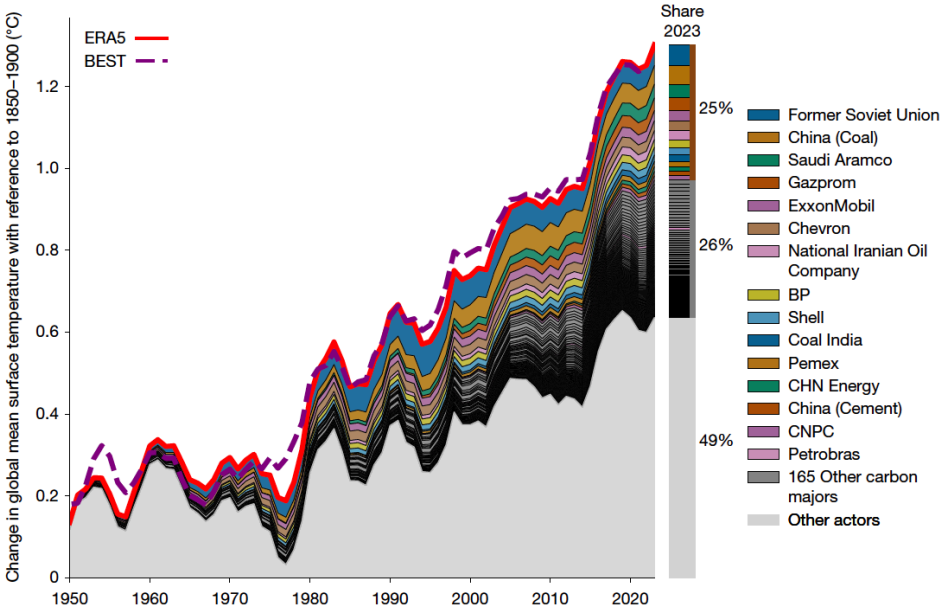
fuel company extraction rates to global climate goals, and given my interest in the emissions embedded in proven reserves, we and our co-authors agreed to investigate the alignment of 142 major oil, gas, and coal companies with the 1.5°C climate targets, using Carbon Majors dataset (augmented with Chinese coal company data) of production from 2014 to 2020, and evaluating their production against three IPCC 1.5°C pathways, finding that ~two-thirds of coal, oil and gas companies "produced more than their production budgets under the IPCC's middle-of-the-road Paris Agreement-compliant scenario."[34]

Attribution of heatwaves to Carbon Majors

Among the most persistent impacts of global warming and threat to human health and mortality is the rise in average daily and nighttime temperatures around the world, including in regions unaccustomed to extreme temperature excursions. Eleven colleagues and I analyzed 213 heatwaves that occurred on all seven continents from 2000 to 2023 that incurred casualties or economic losses or calls for international assistance in a paper published in *Nature* in 2025.[35] We used the emissions traced to Carbon Majors and evaluated whether responsibility for heatwaves' probability of occurrence and intensity could be attributed to major fossil fuel companies.

We found that anthropogenic global warming has made heatwaves as much as 200 times more likely 2010-2019 compared to the baseline period from 1850 to 1900, that the emissions traced to 180 Carbon Majors account for 57% of CO_2 emissions from 1850 to 2023, including land use emissions, and that proportional responsibility for increase in average temperature and occurrence and intensity of heatwaves can be attributed to individual fossil fuel producers.

Figure 7. Major fossil fuel producers' contribution to cumulative atmospheric CO_2 since 1850



Quilcaille et al. 2025) Figure 3b. Contributions of the carbon majors to the cumulative CO_2 emission since 1850.

The seven largest investor- and state-owned fossil fuel producers —oil & gas giants Saudi Aramco, Gazprom, ExxonMobil, Chevron, National Iranian, BP, and Shell — have collectively contributed 12.5% of all anthropogenic CO_2 emissions 1850-2023 (18.12% of fossil fuel & cement CO_2),

[34] Rekker, Saphira, Guangwu Chen, Richard Heede, Matthew Ives, Belinda Wade, & Chris Greig (2023) Evaluating fossil fuel companies' alignment with 1.5°C climate pathways, *Nature Climate Change*, vol. 13:927-934, online 14 August. https://www.nature.com/articles/s41558-023-01734-0

[35] Quilcaille, Yann, Lukas Gudmundsson, Dominik L. Schumacher, Thomas Gasser, Richard Heede, Corina Heri, Quentin Lejeune, Shruti Nath, Philippe Naveau, Wim Thiery, Carl-Friedrich Schleussner, & Sonia I. Seneviratne (2025) Systematic attribution of heatwaves to the emissions of carbon majors, *Nature*, vol. 645:392-398, 11 September. URL: https://www.nature.com/articles/s41586-025-09450-9

contributed 14.6% of increased heatwave intensity, and increased the probability of occurrence of heatwaves by 11.5x.

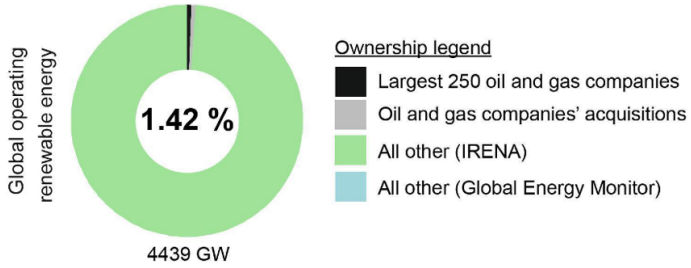
Lead author Yann Quilcaille added that "preindustrial probability and intensity of the heatwaves have increased for all events due to the emissions from ExxonMobil," and "45% of the 213 heatwaves [analyzed] were made 1.1 to 10 times more likely compared to the preindustrial level because of ExxonMobil alone."[36]

> *Owing to global warming since 1850–1900, the median of the heatwaves during 2000–2009 became about 20 times more likely, and about 200 times more likely during 2010–2019. Overall, one-quarter of these events were virtually impossible without climate change. The emissions of the carbon majors contribute to half the increase in heatwave intensity since 1850–1900. Depending on the carbon major, their individual contribution is high enough to enable the occurrence of 16–53 heatwaves that would have been virtually impossible in a preindustrial climate. We, therefore, establish that the influence of climate change on heatwaves has increased, and that all carbon majors, even the smaller ones, contributed substantially to the occurrence of heatwaves*. — Quilcaille et al. Quoted from abstract.

Public institutions should cut ties with fossil fuel companies

A team of colleagues, led by Llavero-Pasquina and Antonio Bontempi of the University of Barcelona, assessed major fossil fuel companies' generation of renewable energy as a fraction of the energy content of their oil, gas, and coal extraction (globally averaged 1.42%; Figure 8).

Figure 8. 250 largest oil & gas companies



Llavero-Pasquina et al. (in review) Figure 1a, "The largest 250 oil and gas companies, representing 88% of global oil and gas extraction, only contributed to 1.42% of global renewable energy deployment as of 2024."

We critique the oil and gas industry's claims of taking significant action to reduce emissions by focusing on operational scope 1 and scope 2 emissions (some 12 to 20% of each company's total attributed emissions) while ignoring and denying responsibility for emissions from use of their products, i.e., from combustion of each fuel's carbon content. We point out that the industry spent ~$20 billion on renewable energy, which is only 3% of the industry's total capital budget, among other industry claims that do not comport with the Paris Agreement's 1.5°C requirements.

We also propose a "Paris Compatibility Test" with three primary conditions: first, halt fossil fuel exploration and development, second, decommission producing assets that exceed the carbon budget under the Paris Agreement 1.5°C scenario, and third, not defer fossil fuel emissions (from scope 3 emissions from sold products) reductions through carbon offsets, CCS, or renewable energy deployment. We evaluate two companies with respect to the Paris Compatibility Test: TotalEnergies, despite repeated claims of shifting away from fossil fuels and supporting the transition to clean energy, fails all three Paris-compliant conditions, whereas Ørsted (a previous oil and gas producer that divested fossil fuel production years ago, and transitioned to a renewable energy company), not surprisingly, meets all three conditions. We conclude that nearly all oil and gas companies would fail the Paris Compatibility Test, and supports our recommendation that public institutions sever their relationships with those companies. Continuing those relationships fails to meaningfully advance crucial and increasingly rapid decarbonization.

[36] Personal communication, November 2025.

Conclusions

Have we met our objective of holding the fossil fuel industry accountable for climate impacts and climate damages? No, not yet. Legal cases are winding their way through dozens of jurisdictions around the world, legislative efforts are underway to demand "cost recovery" payments from oil and gas companies, shareholder and investors continue to urge companies to account for scope 3 product emissions. It will take years for these efforts to play out. Meanwhile, oil and gas companies appear confident that they will prevail and retain their social license to operate to continue to invest $-billions to tens of $-billions into exploration, development, and production of additional oil and gas reserves that should be stranded.

Humanity has an urgent need and an urgent duty to curb global carbon emissions to zero as rapidly as possible. Holding Carbon Majors accountable for their past, present, and continuing role in those emissions is a critical contribution to this effort. The objective of my work has been, and remains, to quantify the basis, scale, and scope of that accountability.

Henry Shue, University of Oxford, Dept. of Politics and International Relations, said in his deeply insightful *Commentary* to our paper that: [37]

> *The time has come for the major carbon producers to face the reality of the unsafe products they persist in marketing and the safer world they could help to create. Otherwise, they risk turning themselves into enemies of humanity…*
>
> *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.*

Peter Frumhoff, then UCS director of science and policy (now Harvard and Woods Hole), 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 op-ed by Frumhoff & Allen.)[38]

Jeff Goodell frames it this way:[39]

> *The simple truth is, the climate accountability genie is out of the bottle, and the Supreme Court is unlikely to jam it back in. Even if the court sides with Suncor, attribution science will continue to move forward, filling in the gaps between cause and effect in our understanding of how climate works.*

In closing, I can say it no better than the editors of *The Guardian* did in September 2017 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.*

Aim high, and keep working for climate justice,

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[37] Shue, Henry (2017) Responsible for What? Carbon Producer CO_2 Contributions and the Energy Transition, Springboard Commentary on Ekwurzel et al., *Climatic Change*, vol. 144:591-596, online 7Sep. https://link.springer.com/article/10.1007/s10584-017-2042-9.

[38] 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

[39] Goodell, Jeff (2026) The Science That Has Oil Companies Running Scared, New York Times, Guest Essay, 6 October. https://www.nytimes.com/2026/10/06/opinion/oil-companies-supreme-court.html?

Addendum:

Climate Accountability Institute has shifted the work of updating the Carbon Majors database to InfluenceMap. The London-based organization has put tremendous effort into updating every entity to 2024 production and emissions, using the same methodology as Carbon Majors, and has expanded the number of entities to 180. I congratulate Emmett Connaire, Daan Van Acker, and Dylan Tanner upon the data release; I am very grateful for their long hours and close collaboration on this mission.

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