Fossil fuel companies' true balance sheets

Carl-Friedrich Schleussner[1,2], Marina Andrijevic[3], Jarmo Kikstra[3,4], Richard Heede[5], and Joeri Rogelj[3,4]

[1]Climate Analytics
[2]Geography Department, Integrative Research Institute on Transformations of Human-Environment Systems (IRI THESys, Humboldt-Universität zu Berlin
[3]International Institute for Applied Systems Analysis (IIASA)
[4]Grantham Institute for Climate Change and the Environment and Centre for Environmental Policy, Imperial College London
[5]Climate Accountability Institute

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[1] Climate Analytics, Berlin, Germany
[2] Integrative Research Institute on Transformations of Human-Environment Systems (IRI THESys) and the Geography Department, Humboldt-Universität zu Berlin, Berlin, Germany.
[3] International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.
[4] Grantham Institute for Climate Change and the Environment and Centre for Environmental Policy, Imperial College London, London, UK.
[5] Climate Accountability Institute, Snowmass, CO, USA

Societal damages caused by emissions attributable to fossil fuel companies estimated to be of the order of several trillion US dollars.

As impacts of human-caused climate change increasingly damage lives, livelihoods and economies, the question of compensation and support for those affected becomes ever more pressing[1]. On the international level, climate related Loss and Damage has been discussed for decades under the United Nations Framework Convention on Climate Change (UNFCCC)[2]. Political sensitivities around questions of liability and compensation, however, have long hindered progress on this issue[3]. It is therefore a breakthrough that the 2022 climate summit in Sharm el-Sheikh decided to establish a new fund and arrangements to address loss and damage associated with the adverse effects of climate change[4].

The decision calls for identifying "potential sources of funding, recognizing the need for support from a wide variety of sources, including innovative sources". This clearly points beyond classical sources of climate finance (that typically are provided by governments or multilateral institutions) to also include non-state and private sector actors. Contributions from the private sector, and specifically fossil fuel companies, to a Loss and Damage fund have been explicitly called for by Leaders of Small Island States[5].

The calls for the fossil fuel sector to contribute are predicated on both the significant share of historic greenhouse gas emissions that are attributable to only a small number of so-called 'carbon major' companies[6], and the well-documented effort of several of those companies to deny and obscure the scientific evidence on climate change[7]. Over the 1965-2018 period, more than one third of the global fossil carbon dioxide and methane emissions can be attributed to only twenty investor- and state-owned fossil fuel companies when considering the extraction and use of their fossil fuel products[8]. At the same time, the fossil fuel industry has been well aware of the potential consequences of their fossil fuel products for decades, and in the case of

ExxonMobil even conducted state-of-the-art projections of global warming as early as 1977[9]. However, instead of taking appropriate action based on their insights, many companies chose to promote the spread of false and misleading claims on climate change[7].

This dual moral failure of continued emissions and pro-active undermining of a scientific and subsequent political consensus on the need to address climate change has significantly contributed to human-induced global warming continuing to the level it is at today and the widespread adverse impacts and related losses and damages it has caused[1,9]. Observed climate change also had profound negative effects on the economic output of many developing countries in the tropics thereby contributing to increasing global economic inequality[10].

The case for a contribution by the fossil fuel industry to a Loss and Damage funding arrangement can thus be made, though the exact financial volume is yet to be established. Quantifying the costs of climate change is notoriously difficult and requires a range of methodological and ethical assumptions[11]. One of the most established approaches is reflected in estimates of the social cost of carbon (SCCO2) as the net-present value of future net damage to society of emitting one additional tonne of CO_2[12]. Here, we suggest that the SCCO2 can provide an indication of the scale of projected damages of historic CO_2 emissions attributable to fossil fuel companies. In order to do so, we take inspiration from established approaches of attribution of future climate impacts to individual emitters against the counterfactual of a world without those emissions[13,14]. In this approach, we look only at the future impacts of the total already emitted CO2 of each emitter, while following standard approaches for future discounting. The SCCO2 is calculated as the marginal impacts of CO2, meaning that the emissions quantities looked at for each entity should not constitute a substantial change in the climate system. We find this to be the case given that the cumulative emissions attributable to individual fossil fuel companies since 1985 amount to less than 2 years of today's global fossil fuel emissions. In an alternative approach, we calculate the net damage to society under the assumption that the net damages are discounted from the time of emission rather than from present day. Assuming that marginal damages of CO2 are zero at pre-industrial temperature levels, we adjust historical emissions downward based on lower global temperatures (see Methods). Since the latter approach would mix historically discounted and future damages, we use the time-invariant approach in the main text. In addition, a discounting of historic emissions strongly benefits historic emitters mainly from developed countries and might be contestable on the grounds of equity and fairness. We report the time-adjusted values in the Supplementary Material.

We do not assess the damages attributable to methane emissions, but including these would result in consistently higher damages and derived financial consequences. As a central estimate we choose the recent preferred SCCO2 estimate from ref. [12] of 185 USD per tonne of CO_2. This is similar to the value recommended by the Environmental Protection Agency (EPA) of the United States, with a 2% discount rate[15] (Table S1). To also capture a range of uncertainty in estimating costs and damages, we provide the 5th-95th percentile range of ref. [12], from 44 to 413 USD. This range comprises many SCCO2 estimates suggested in the recent literature, although substantially higher values cannot be ruled out for a variety of reasons, such as including more economic sectors and non-monetizable impacts, considering equity weighting of damages, or changing the representation of indirect costs and damage persistence[16,17].

Our results suggest that the damages attributable to the emissions by individual fossil fuel companies over the 1985-2018 period may be of the order trillions of USD per company. To put those numbers in perspective, we compare them with recent estimates of accumulated oil and gas rents over the same time period for fossil fuel companies, both state and investor-owned (compare Fig. 1a and 1b, and Tab. S2 and S3, respectively). We find that the damages implied by attributable emissions are comparable to, and for the central SCCO2 estimate even exceed, the cumulative oil and gas rents over the same period for all companies and countries considered. It is important to highlight that both the damages and the accumulated rent estimates come with profound uncertainties. Adopting a time variant SCCO2, for example, leads to overall lower values, yet of the same order of magnitude (compare Fig. S6).

In several instances, accumulated fossil fuel revenues have provided the basis for the establishment of national “sovereign wealth funds” (SWFs), such as the Government Pension Fund of Norway or the Abu Dhabi Investment Authority[18]. SWFs have been established at different times in different countries, and the share of fossil generated revenues added to the funds also differs. The volume of those funds to date also comprises significant other sources of revenue based on their investments, but the basis of their existence are fossil fuel rents. The three biggest fossil-based SWFs are owned by Norway, the United Arab Emirates and Kuwait. Even for these countries, the volume of the SWFs barely comes close to, and in the case of Norway, just about matches the median damage estimates (compare Fig. 1a and Tab. S2). In the light of the extensive damages caused by the emissions attributable to the fossil revenue sources of the funds, we believe it is appropriate to reflect whether or not SWFs should only benefit the citizens of the respective countries, or if a more global responsibility can be argued for. Their potential contribution to a Loss and Damage fund might merit particular consideration, given that these funds are government owned and controlled.

For investor-owned companies, it is less transparent who has benefited from the rents accrued over time. The biggest share of it has contributed to the operations and asset stock of the companies, but a significant part has also been dispersed to investors. This does not mean that those emissions should go unaccounted for. Rather, it points to the importance of comprehensive reporting of indirect emissions for the private sector, i.e. as part of their scope 3 emissions reporting[19], and a reflection on potential liability for the damages implied by them.

Record profits of fossil companies in 2022 have received a lot of public and political attention as they coincide with a period of a global and economic crisis. Our results show that even these record profits do not match the central estimates for the damages caused by the emissions attributable to those companies for a single year (of the order of up to several 100 billion USD, compare Fig. 2 and Tab. S4).

The question whether fossil fuel companies, their shareholders, or fossil-based SWFs should contribute to Loss and Damage funding is of course not scientific but political. Current political discussions highlight and exemplify this, for example, in the United Nations Secretary-General's call to tax the windfall profits of fossil fuel companies[20] for precisely that purpose. The simple comparison presented here does not yet provide a robust basis for quantitative claims, but points towards the role that capital accumulated through fossil fuel extraction might need to play in dealing with the loss and damage it has been and continues to be causing.

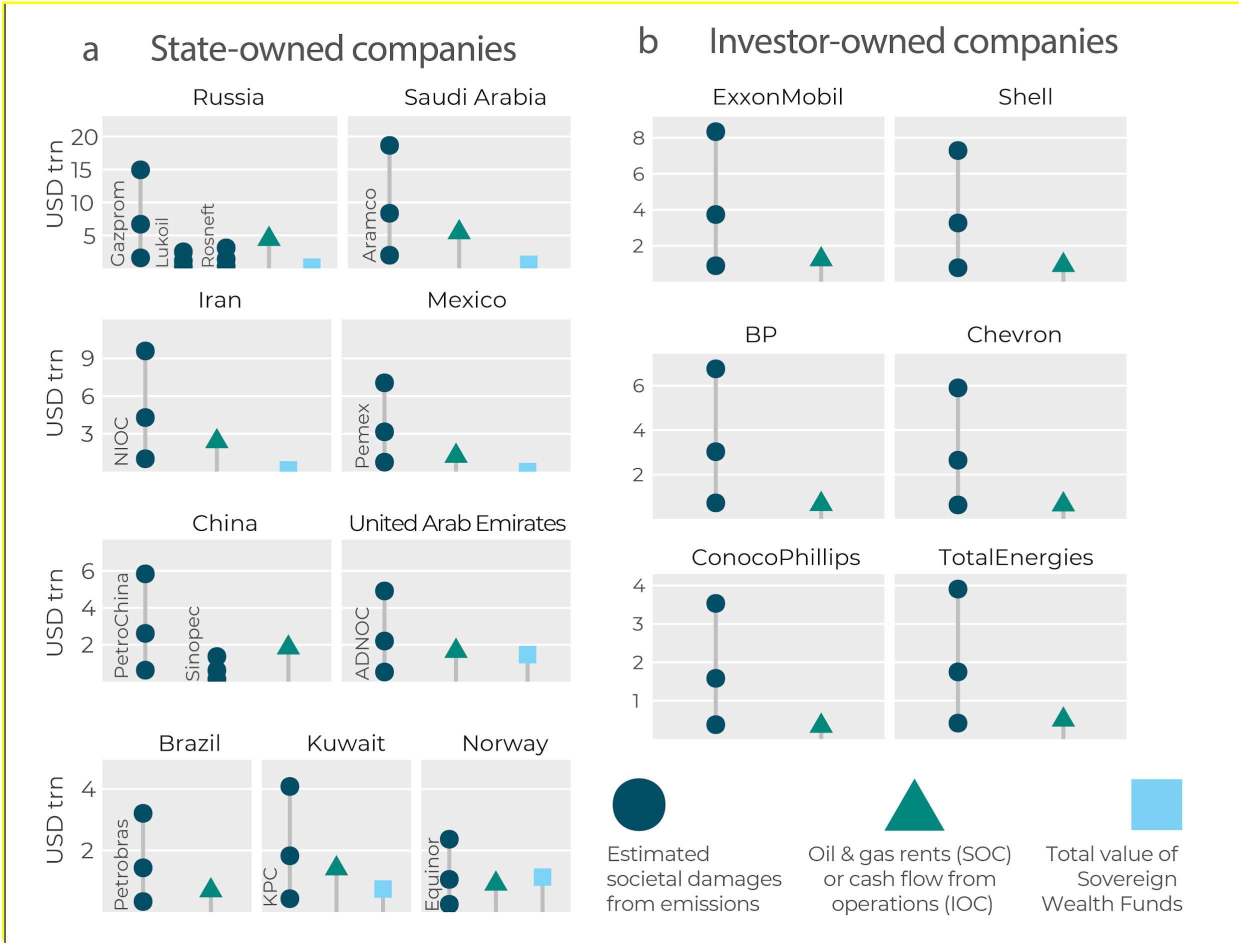

Fig 1| Cumulative oil and gas rents vs estimated societal damages from emissions. Estimated societal damages from CO2 emissions over the 1985-2018 period attributable to fossil fuel companies for different estimates of the social costs of carbon dioxide (central estimate and 5-95% range based on ref. [12].). **a,** State-owned companies for which the oil and gas rents are derived following a methodology deployed in ref. [21]. Where applicable, the total value of national, fossil-revenue based Sovereign Wealth Funds is shown for comparison. **b,** Investor-owned companies for which the cumulative cash-flow from operations over the 1985-2018 period is derived. All values are provided in 2020 USD.

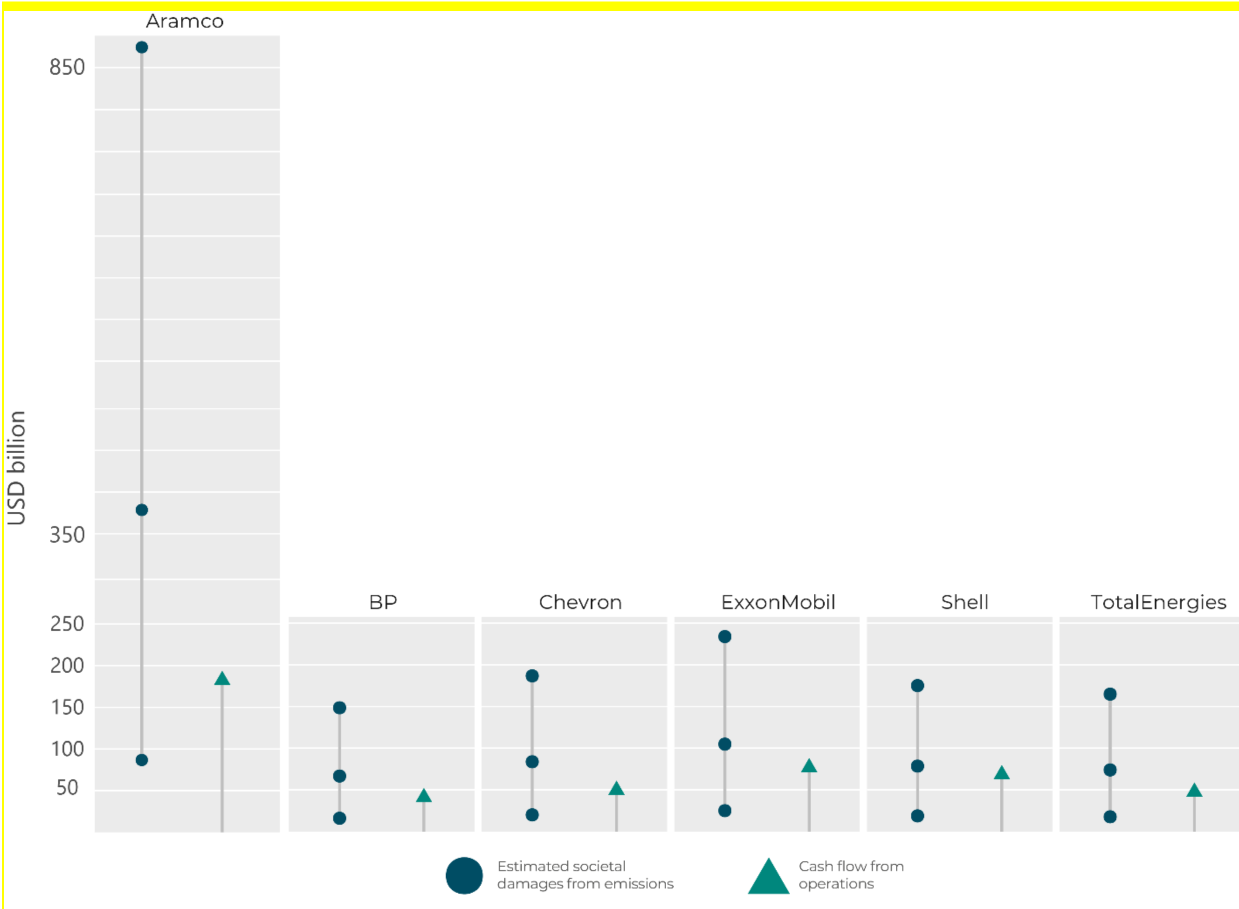

Fig 2| Oil and gas rents vs estimated societal damages from emissions for selected companies. Estimated societal damages from 2022 CO2 emissions attributable to fossil fuel companies for different estimates of the social costs of carbon dioxide (central estimate and 5-95% range based on ref. [12].) compared to the cash-flow from operations for the year 2022 (all numbers in 2022 USD).

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Competing interests
The authors declare no competing interests.

Supplementary Material - Fossil fuel companies' true balance sheets

Carl-Friedrich Schleussner[1,2], Marina Andrijevic[3], Jarmo Kikstra[3,4], Richard Heede[5], Joeri Rogelj[3,4]

[1] Climate Analytics, Berlin, Germany
[2] Integrative Research Institute on Transformations of Human-Environment Systems (IRI THESys) and the Geography Department, Humboldt-Universität zu Berlin, Berlin, Germany.
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[4] Grantham Institute for Climate Change and the Environment and Centre for Environmental Policy, Imperial College London, London, UK.
[5] Climate Accountability Institute, Snowmass, CO, USA

Material and Methods

Calculation of economic climate damages based on the social cost of carbon dioxide

We provide two alternative calculations of the economic damages attributable to the historic emissions of fossil fuel companies. The first calculation derives the marginal difference today without the cumulative emissions of a certain entity. To calculate this value, we multiply the cumulative CO2 emissions of that entity with the social cost of carbon dioxide (SCCO2) for 2020 (Figure S1), to provide the total net damages to society. This is following established approaches of attribution to individual emitters[13,14] and rests on the central insight that the timing of emissions of a unit of CO2 is irrelevant as the warming impact depends on the cumulative emissions over time.

The second calculation takes a different perspective, namely that emissions at earlier times caused marginal increases in global temperature at a lower level. It is then assumed that therefore the damage linked to these emissions would also be lower. To approximate this effect, we first assume that there are no initial costs or benefits from climate change, in a similar fashion to previous work[22]. Further assuming that the SCCO2 increases quadratically with temperature, we backcast SCCO2 values using a LOESS on the historical global average temperature from three sources (Figure S2, Figure S3). Consequently, the applied SCCO2 follows:

SCCO2[yr] = a * T[yr]^2,

where

a = SCCO2_2020 / ((T_2020)^2)

We also add a second sensitivity case, which is a linear scaling, following:

SCCO2[yr] = a * T[yr],
where
a = SCCO2_2020 / T_2020

The LOESS of the average of the temperature records is very close to the assessed global warming levels in the Sixth Assessment Report of the IPCC (IPCC, 2021), at a difference of -0.04°C for both the 2001-2020 and the 2011-2020 periods.

Calculation of oil and gas rents

The World Bank expresses oil and gas rents as the share of GDP, that is derived by subtracting the average cost of producing the commodity from its price, and multiplying by the quantity of the commodity extracted. Costs of production includes a “normal” rate of return on fixed capital and the consumption of fixed capital[23].

To derive oil and gas rents in absolute monetary terms, we follow the approach used in ref [21] for global estimates, and apply it to the country level: inflation-adjusted country-level GDP in year n is multiplied by the share of GDP that is attributed to oil and gas rents.

It should be noted that the estimates of oil and gas rents contain a degree of uncertainty stemming from the difficulty of always precisely observing the costs of production or because they vary over the lifetime of an extraction project.

Investor-owned companies

For Investor based companies we use data from Bloomberg Finance covering the period 1985-2018[24]. Data coverage before 1985 is insufficient for an analysis. For transparency reasons we show cash flow from operations for individual companies, rather than reported profits. For 2022 we gather the data directly from each company’s financial statement. A comparison between reported cash flow from operations and profits is provided in Figs. S4 and S5.

Data availability

Data underlying the analysis and figures presented is included in a public repository (see Code Availability Statement) with the exception of the financial data (cash flow from operations and net earnings/profits) for the historical period (1985-2018) that was obtained from a proprietary source (Bloomberg Finance) and needs to be procured from the data provider.

Code availability

The script used to process the data and generate the main plots in this manuscript are available at: 10.5281/zenodo.7660070

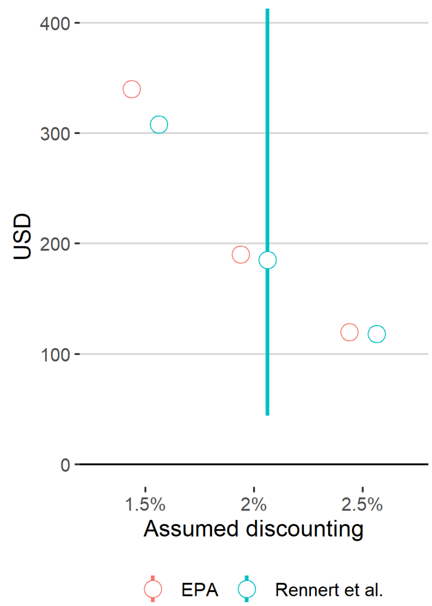

Fig. S1 | A selection of recent estimates of the social cost of carbon dioxide (SCCO2) expressed in USD2020/tCO2. For the central 2% discount rate of ref [12] the 5th to 95th percentile of the SCCO2 estimate range is shown in addition to central estimates for all selected cases.

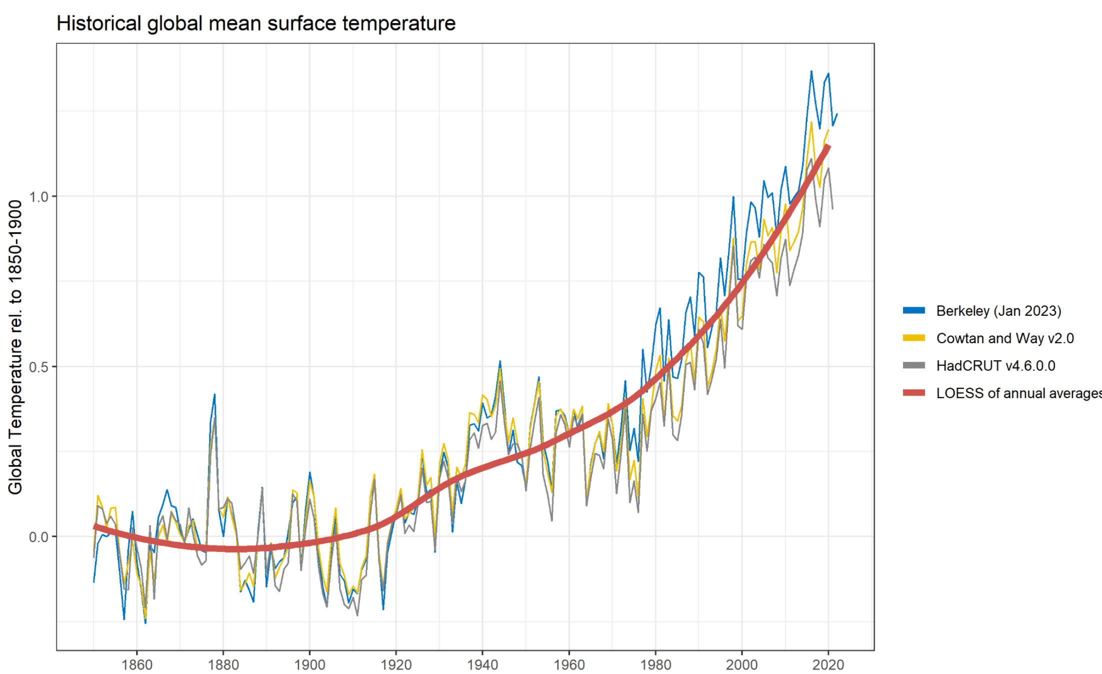

Fig. S2| Observed changes in global mean surface air temperature. Time series are shown for three different datasets (Berkeley Earth[25], Cowtan & Way[26] and HadCRUT 4.6[27]) and for a LOESS smoothing after taking the mean of the three in each year, with the base period 1850-1900. This smoothed average is used to estimate the temperature increase used to scale the SCCO2.

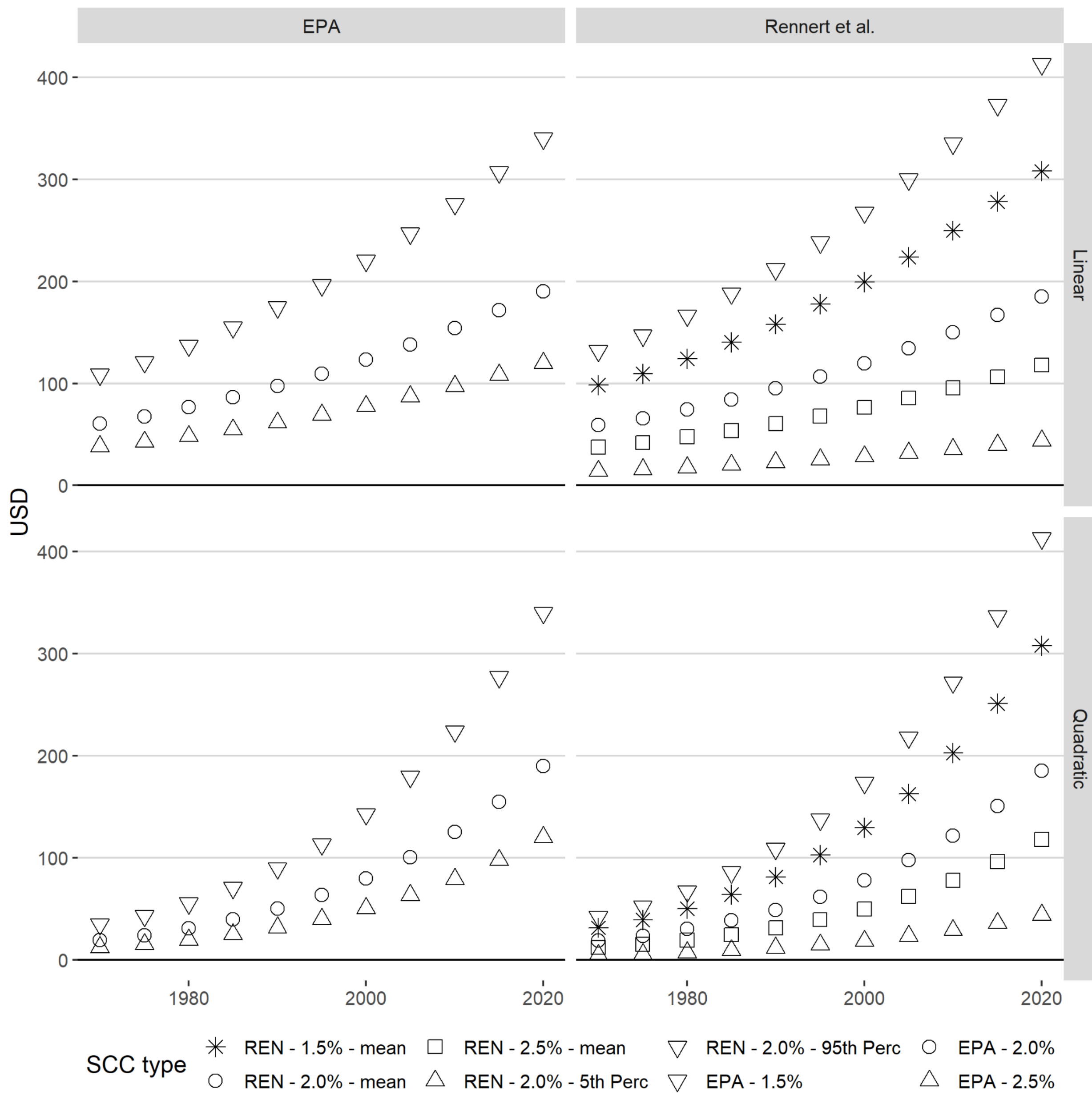

Fig. S3| A range of global social cost of carbon dioxide (SSCO2). Estimates for 2020 are shown from ref. [12] and ref. [15], with values before 2020 estimated using the assumption that the SSCO2 is quadratic function of temperature and zero at the point of no global warming, following the assumption in ref. [22] based on a LOESS global temperature time series (compare Fig. S2).

Table S1| Overview of different social cost of carbon dioxide estimates.

SSCO2 value	Type of estimate	Discount rate	Sectors included	Source
118	mean value of MC	2.50%	(4) agriculture, energy, mortality, sea-level rise [coastal regions]	Rennert et al. 2022, figure 2: https://www.nature.com/articles/s41586-022-05224-9/figures/2
185	mean value of MC	2.00%	(4) agriculture, energy, mortality, sea-level rise [coastal regions]	Rennert et al. 2022, figure 2: https://www.nature.com/articles/s41586-022-05224-9/figures/2
308	mean value of MC	1.50%	(4) agriculture, energy, mortality, sea-level rise [coastal regions]	Rennert et al. 2022, figure 2: https://www.nature.com/articles/s41586-022-05224-9/figures/2
44	5th percentile of MC	2.00%	(4) agriculture, energy, mortality, sea-level rise [coastal regions]	Rennert et al. 2022, figure 2: https://www.nature.com/articles/s41586-022-05224-9/figures/2
413	95th percentile of MC	2.00%	(4) agriculture, energy, mortality, sea-level rise [coastal regions]	Rennert et al. 2022, figure 2: https://www.nature.com/articles/s41586-022-05224-9/figures/2
190	rounded assessed/recommended estimate	2.00%	multiple lines of evidence	EPA, page 3 of Exec Summary, https://www.epa.gov/system/files/documents/2022-11/epa_scghg_report_draft_0.pdf
120	rounded assessed/recommended estimate	2.50%	multiple lines of evidence	EPA, page 3 of Exec Summary, https://www.epa.gov/system/files/documents/2022-11/epa_scghg_report_draft_0.pdf
340	rounded assessed/recommended estimate	1.50%	multiple lines of evidence	EPA, page 3 of Exec Summary, https://www.epa.gov/system/files/documents/2022-11/epa_scghg_report_draft_0.pdf

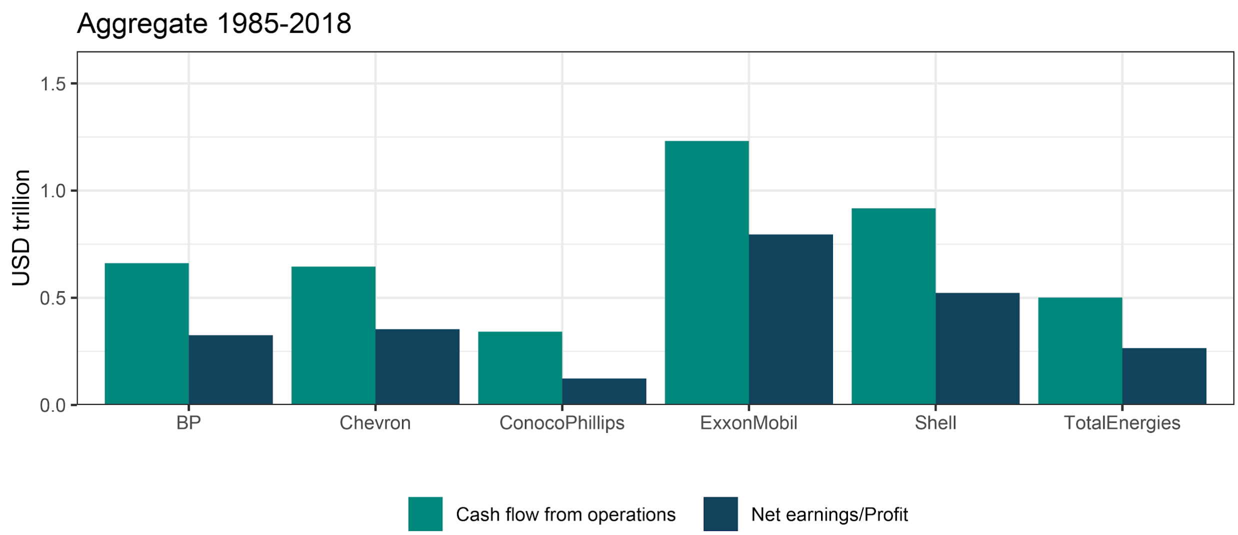

Fig. S4| Comparison of cash flow from operations and profits for selected companies aggregated over the 1985-2018 period.

Fig. S5| Comparison of cash flow from operations and profits for selected companies aggregated for the year 2022.

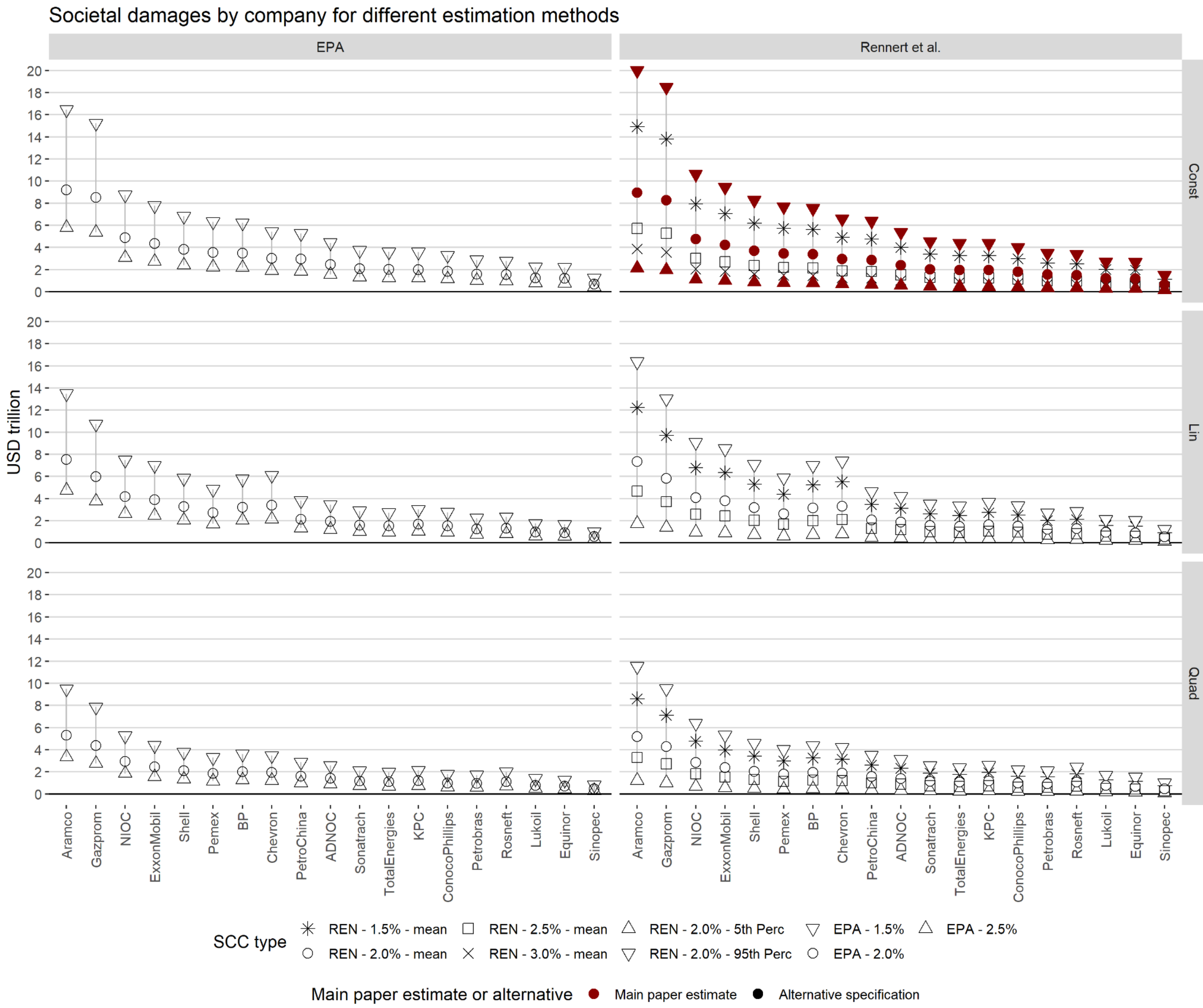

Figure S6| Estimate societal damages per company for SCCO2 estimation methods. Estimates are shown for constant 2022, linear and quadratically increasing SCCO2 (top, middle and bottom panel, respectively) and estimates based on different quantiles and discount rates based on ref. [12] and ref. [15].

Table S2| Aggregate emissions, societal damages and financial figures associated with state-owned companies from 1985 to 2018 (Fig 1a). All numbers are reported in USD 2020.

Country	Company	Total emissions (MtCO2)	Societal damages (USD trn)			Oil and gas rents (USD trn)	Sovereign Wealth Funds (USD trn)
			5th percentile (SCC USD 44)	Mean (SCC USD 185)	95th percentile (SCC USD 413)		
Brazil	Petrobras	8,241	0.3	1.4	3.2	0.7	NA
China	PetroChina	14,144	0.6	2.6	5.8	1.8	NA
China	Sinopec	3,300	0.1	0.6	1.4	1.8	NA
Iran	National Iranian Oil Co.	31,448	1.0	4.3	9.6	2.4	0.1
Kuwait	Kuwait Petroleum Corp.	12,847	0.4	1.8	4.1	1.4	0.8
Mexico	Pemex	20,558	0.8	3.2	7.1	1.2	0.0
Norway	Equinor	5,911	0.3	1.1	2.4	0.9	1.1
Russia	Gazprom	36,176	1.6	6.7	14.9	4.4	0.2
Russia	Lukoil	6,079	0.3	1.1	2.5	4.4	0.2
Russia	Rosneft	7,514	0.3	1.4	3.1	4.4	0.2
Saudi Arabia	Saudi Aramco	56,959	2.0	8.4	18.6	5.4	0.6
United Arab Emirates	Abu Dhabi NOC	13,287	0.5	2.2	4.9	1.7	1.5

Table S3| Aggregate emissions, societal damages and financial figures associated with investor-owned companies from 1985 to 2018 (Fig 1b). All numbers are in USD 2020.

Company	Total emissions ($MtCO_2$)	Societal damages (USD trn)			Cash flow from operations (USD trn)
		5th percentile (SCC USD 44)	Mean (SCC USD 185)	95th percentile (SCC USD 413)	
BP	27,536	0.7	3.0	6.8	0.7
Chevron	32,179	0.6	2.6	5.9	0.6
ConocoPhillips	12,176	0.4	1.6	3.5	0.3
ExxonMobil	32,528	0.9	3.7	8.3	1.2
Shell	26,113	0.8	3.3	7.3	0.9
TotalEnergies	10,675	0.4	1.8	3.9	0.5

Table S4| Aggregate emissions, societal damages and financial figures associated with investor-owned companies for 2022 (Fig 2). All numbers are reported in USD 2022.

Company	Total emissions (MtCO2)	Societal damages (USD bn)			Profit/Net earnings (USD bn)	Cash flow from operations (USD bn)
		5th percentile (SCC USD 44)	Mean (SCC USD 185)	95th percentile (SCC USD 413)		
Aramco	1857	92.3	388.2	866.6	161.1	186.2
BP	318	15.8	66.4	148.8	27.7	40.9
Chevron	400	19.8	83.6	186.1	36.5	49.6
ExxonMobil	501	24.9	104.7	233.8	55.7	76.8
Shell	375	18.6	78.4	175.0	39.9	68.4
TotalEnergies	353	17.5	73.4	164.7	36.2	47.4