

Supplementary Materials.

Heede and Oreskes, Potential emissions of CO₂ and methane from proved reserves of fossil fuels: An alternative analysis, *Global Environmental Change*. DOI: 10.1016/j.gloenvcha.2015.10.005.

The methodology.

For a full description of the methodology, see Heede (2013, 2014).

1. Gather statements of proven recoverable reserves of oil and condensates, unconventional oils, NGLs, natural gas, and coal (by coal rank) from company sources based on SEC reporting rules (for entities that file reserve estimates with the SEC), or based on other international reserve protocols, such as the Society of Petroleum Engineers' Petroleum Resources Management System (PRMS), estimates collected by the *Oil & Gas Journal* (particularly for state-owned oil and gas companies), company websites and annual reports, and other sources;
2. Calculate potential emissions from the production and marketing of each entity's recoverable reserves from the emission factors listed in Table 1, subtracting for non-energy uses of carbon;
3. Calculate additional emissions from flaring of associated gas, CO₂ vented from natural gas processing, and vented and fugitive methane from oil, natural gas, and coal production, refining, and transportation. These factors are listed in Table 2;
4. For coal reserves, account for heating values and emission factors of differing coal ranks for each entity; reserves may differ in heating value from an entity's current production from various mining complexes, but this variability is likely to be small;
5. Sum potential emissions from each entity's stated reserves by fuel and additional emissions from venting and flaring of CO₂, and fugitive methane. All oil companies also produce natural gas, gas companies such as BG or Gazprom also list NGL or condensate reserves, some entities produce both liquid and solid fuels (e.g., BHP Billiton), and CONSOL Energy produces and reports gas reserves from coal-bed methane recovery;
6. Calculate the potential CO₂ emissions from the 70 investor-owned and state-owned entities and 8 nation-states as a percentage of estimated remaining emissions budget of 275 GtC (IPCC 2013).

For example, ExxonMobil lists 13.24 billion bbl and 71.86 Tcf of proven recoverable reserves of crude oil & NGL and natural gas, respectively, in its SEC Form 10-K filed for 2013. Thus 13.24 billion bbl times the emission factor for oil & NGL (0.3714 tCO₂/bbl) in Table 1 = 4.92 GtCO₂, plus 71.86 Tcf times 0.0534 tCO₂/kcf = 3.84 GtCO₂, which total 8.76 GtCO₂. Additional emissions from venting (85 MtCO₂), flaring (128 MtCO₂), and fugitive methane (995 MtCO₂) total 1.21 GtCO₂e. Potential emissions from the production of ExxonMobil's recoverable reserves thus total 9.97 GtCO₂e. Based on 2013 production rates and proved reserves, ExxonMobil has a 15-yr reserve-to-production ratio (14 yrs oil and 17 yrs for gas).

Coal reserves.

The majority of coal reserves are held by the 8 nation-states, primarily China and the Russian Federation. China: 115 Gt, Czech Republic: 1.1 Gt, Kazakhstan: 34 Gt, North Korea: 0.6 Gt, Poland: 5.5 Gt, Russian Federation: 157 Gt, Slovakia: 0.3 Gt, Ukraine: 34 Gt. World Energy Council (2013), BP (2014b). Other countries with large coal reserves, such as the United States (237 Gt), Australia (76 Gt), India (61 Gt), and South Africa (30 Gt), are included on the basis of reserves held by multinational coal companies such as Peabody, BHP Billiton, Anglo American, Rio Tinto, and Glencore Xstrata, and national companies such as Sasol and Coal India.

IPCC Remaining Carbon Budget (RCB).

IPCC AR5 WG1 SPM, page 25: "Limiting the warming caused by anthropogenic CO₂ emissions alone with a probability of >33%, >50%, and >66% to less than 2 °C since the period 1861–1880, will require cumulative CO₂ emissions from all anthropogenic sources to stay between 0 and about 1570 GtC (5760 GtCO₂), 0 and about 1210 GtC (4440 GtCO₂), and 0 and about 1000 GtC (3670 GtCO₂) since that period, respectively. These upper amounts are reduced to about 900 GtC (3300 GtCO₂), 820 GtC (3010 GtCO₂),

and 790 GtC (2900 GtCO₂), respectively, when accounting for non-CO₂ forcings as in RCP2.6. An amount of 515 [445 to 585] GtC (1890 [1630 to 2150] GtCO₂) was already emitted by 2011.” For this analysis we select the >66 percent probability budget: 1000 GtC adjusted to 790 GtC for non-CO₂ forcings, minus historic emissions of 515 GtC equals a remaining carbon budget of 275 GtC. This has *not* been reduced by the anthropogenic emissions for 2012-2015, a conservatism of ~40 GtC, nor for land-use emissions that averaged 0.89 GtC/yr over the ten-year period from 2004 to 2013 (Boden et al. 2013).

Fig. SM-1. Major investor-owned, state-owned, and nation-states’ emissions in proven reserves

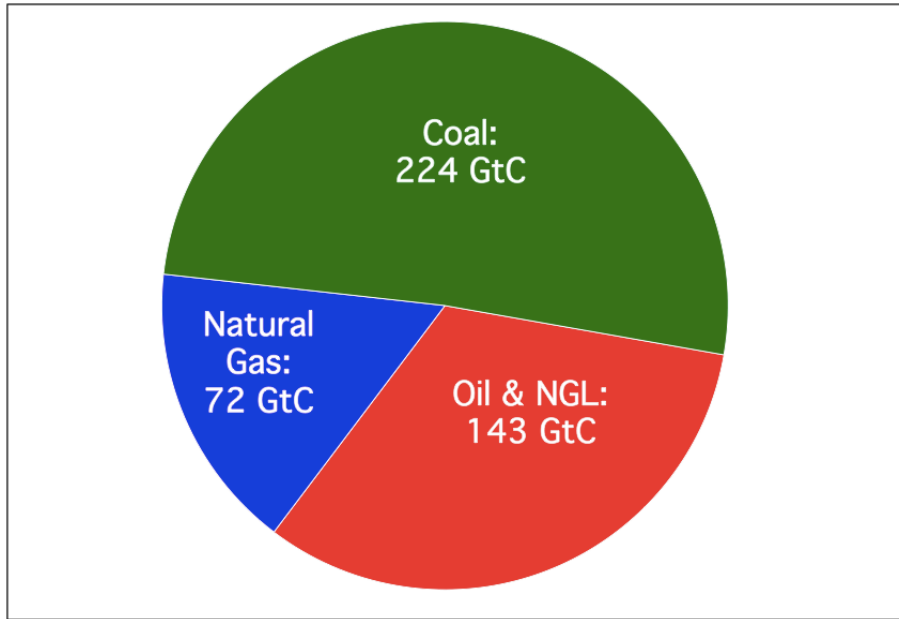


Fig. SM-2. Historic emissions traced to Top Twenty fossil fuel companies, & potential emissions from reserves

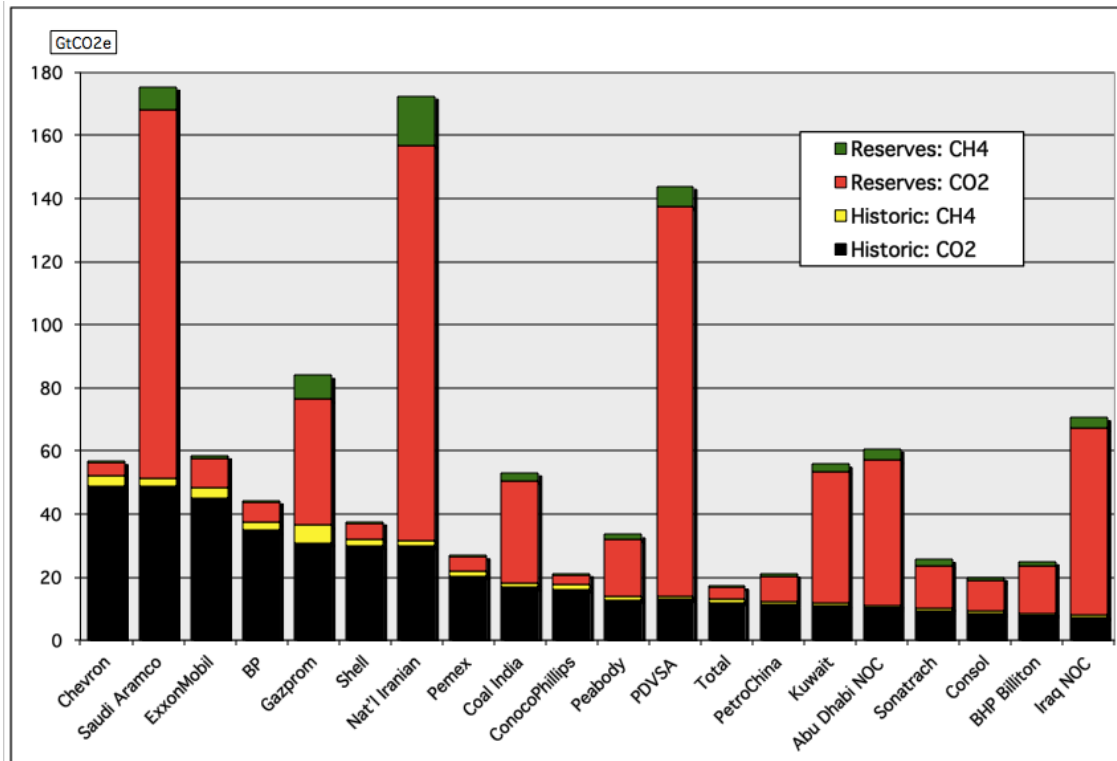


Table SM-1. Investor-owned & state-owned companies: potential emissions from reserves, alphabetized

Entity	Oil & NGL MtCO ₂	Natural Gas MtCO ₂	Coal MtCO ₂	Vented & Flared MtCO ₂	Methane MtCO _{2e}	Total MtCO _{2e}
Abu Dhabi NOC	34,246	10,687		1,001	3,600	49,533
Alpha Natural Resources			10,474		887	11,361
Anadarko	467	492		24	121	1,104
Anglo American			5,656		479	6,136
Apache	566	392		23	104	1,086
Arch Coal			10,603		898	11,501
Bahrain Petroleum	46	174		6	38	264
BG Group	175	290		12	67	544
BHP Billiton	325	541	14,097	23	1,320	16,306
BP	3,740	2,457		148	661	7,006
Canadian Natural Resources	1,642	230		39	114	2,025
Chevron	2,357	1,557		94	418	4,426
China National Offshore Oil Co	1,137	338		33	116	1,623
Coal India			32,293		2,736	35,029
ConocoPhillips	2,051	1,089		74	309	3,523
Consol Energy, Inc.		213	9,422	6	843	10,485
Devon Energy	516	505		25	126	1,172
Ecopetrol	558	120		15	47	740
Egyptian General Petroleum	1,634	4,125		157	922	6,838
EnCana	78	470		16	101	664
ENI	1,144	772		46	922	2,168
ExxonMobil	4,917	3,840		213	995	9,966
Gazprom	3,013	35,836		1,144	7,556	47,549
Glencore Xstrata			9,381		795	10,176
Hess	412	106		11	39	567
Husky Energy	261	126		9	37	433
Iraq National Oil Company	52,111	5,929		1,211	3,341	62,622
Kiewit Mining			718		61	779
Kuwait Petroleum Corp	37,700	3,366		847	2,221	44,135
Libya National Oil Corp.	18,003	2,923		445	1,334	22,704
Lukoil	4,970	1,255		136	461	6,822
Luminant			863		73	937
Marathon	641	143		17	56	856
Murphy Oil	184	62		6	20	271
Murray Energy			1,883		160	2,042
National Iranian Oil Company	58,426	63,741		3,085	15,583	140,835
Nigerian National Petroleum	13,795	9,657		565	2,561	26,578
North American Coal			2,647		224	2,871
Occidental Petroleum	949	297		28	100	1,374
Oil & Gas Corp. India	1,960	1,076		71	302	3,409
OMV Group	236	148		9	40	433
Peabody Energy			18,074		1,531	19,606
Pemex	3,644	884		99	331	4,958
Pertamina	38	42		2	10	92
Petrobras	3,959	603		97	287	4,944
PetroChina	4,019	3,702		192	931	8,845
Petroleos de Venezuela	110,589	10,425		2,503	6,630	130,146
Petroleum Development Oman	2,043	1,603		89	415	4,150
Petronas	4,130	5,130		237	1,231	10,728
Polish Oil & Gas	32	84		3	19	138
Qatar Petroleum	9,375	47,556		1,625	10,244	68,800
Repsol	159	260		11	60	490
Rio Tinto			1,844		156	2,000
Rosneft	11,433	3,523		333	1,193	16,482
Royal Dutch Shell	2,459	2,269		117	570	5,416
RWE			3,730		316	4,046
Sasol	3	84	3,331	3	300	3,721
Saudi Aramco	98,744	15,539		2,423	7,212	123,919
Singareni Collieries			17,601		1,491	19,093
Sinopec	1,058	358		32	117	1,565
Sonangol	3,365	519		82	244	4,210
Sonatrach	4,531	8,499		347	1,946	15,323
Statoil	861	984		47	239	2,131
Suncor	2,860			57	116	3,032
Syrian Petroleum	929	454		32	132	1,547
Talisman	107	261		10	59	437
Total SA	2,011	1,765		93	447	4,316
UK Coal			110		9	119
Westmoreland Mining			583		49	632
Total (MtCO₂)	514,609	257,535	143,312	17,973	86,354	1,019,782
Total (GtC)	140.44	70.28	39.11	4.91	23.57	278.31

All calculations by Richard Heede, Climate Accountability Institute.

Table SM-2. Investor-owned & state-owned companies: potential emissions from reserves, ranked

Entity	Oil & NGL MtCO ₂	Natural Gas MtCO ₂	Coal MtCO ₂	Vented & Flared MtCO ₂	Methane MtCO ₂ e	Total MtCO ₂ e
National Iranian Oil Company	58,426	63,741		3,085	15,583	140,835
Petroleos de Venezuela	110,589	10,425		2,503	6,630	130,146
Saudi Aramco	98,744	15,539		2,423	7,212	123,919
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