CLIMATE ACCOUNTABILITY INSTITUTE

Response to Request for Information on: Development of a Climate Superfund Cost Recovery Program

By Richard Heede
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1 October 2024

To Jane Lazorchak
Director, Climate Action Office
Vermont Agency of Natural Resources
Montpelier, VT

Dear Ms. Lazorchak -

I am pleased to respond to the Agency's Request for Information. In this narrative response I will focus on replying to Questionnaire #1:

> *Describe a stepwise process to identify responsible parties, determine their applicable share of covered greenhouse gas emissions, and determine the cost recovery demand amount as described in Act 122. In doing so, please identify the datasets (publicly available) and describe the methodology and research the approach is based on. Provide an evaluation of the comprehensiveness and accuracy of those data sets. If appropriate, evaluate the utility of using additional information not publicly available to determine cost recovery demands.*

The Agency of Natural Resources (ANR) has been given the task in Act 122 to identify the companies that produced or refined fossil fuels that cumulatively caused the emission of 1 billion tonnes or more of carbon dioxide-equivalent greenhouse gases ($GtCO_2e$) from 1995 to 2024.

This requires two distinct datasets, in stepwise order, and a crucial analysis in step #2:

1. A comprehensive list of domestic and international investor- or state-owned companies that extract or refine fossil fuel resources globally: crude oil and other fossil liquids, fossil gas, and fossil coal;
2. An analysis of which of the companies qualify as "responsible parties" from the perspective of meeting the definition of a constitutionally sound economic nexus with the State of Vermont;
3. Annual data on each company's extraction of fossil fuels or refining of petroleum products for distribution to global consumers over the covered period from 1995 to 2024. The list of included companies and their annual production shall also account for pertinent mergers and acquisitions.

The objective of Act 122 also requires a robust methodology to estimate and attribute emissions from production and/or refining for each responsible party, and on that basis allocate proportional responsibility for damages:

4. A methodology for estimating emissions by global consumers based on quantities of fossil fuel produced and refined;
5. As specified in (§596, 7; §597, 2), the proportional responsibility of "responsible parties" shall be determined on the basis of total "covered greenhouse gas emission" of each entity in the covered period in proportion to global fossil fuel emissions in the covered period.
6. Step #5 provides the allocation factors proportional to their emissions that can be used to quantify cost recovery demands.

In this response to the Request for Information I will discuss applicable data sources and methodological approaches to effectively inform the Agency's task. The results, once completed, can be applied to the cost recovery demands once the damages have been finalized.

1. Identifying major fossil fuel production or refining companies

A number of publicly available sources identify the companies that explore for and discover fossil fuel resources, make infrastructure investments to convert resources into recoverable reserves, extract that oil or natural gas or coal, process or refine that production into marketable carbon fuels, and sell those finished fuels to wholesalers or distribute the finished fuels through their own supply chains to global consumers. Identification of those companies is relatively straightforward, albeit piecemeal, and in my experience it takes reading and collating from diverse sources.[1]

Act 122 states that companies with emissions exceeding 1 billion tonnes CO_2 ($GtCO_2$) are included.

2. Selecting the companies that qualify on the basis of a constitutional nexus with Vermont

Most of the 70 to 80 companies in the list in Appendix Figure A-1 do not have a qualifying economic nexus with the State of Vermont or its citizens or businesses. Parsing the list to include only those companies that qualify, and can thus be legally served with a demand for payment, is a crucial time-saving step prior to the following step #3 of collecting data on prospective "responsible parties" and each of their production or refining of crude oil, natural gas, and coal.

A number of potential criteria need to be considered. For example, fossil fuel producers or refiners that distribute petroleum products such as gasoline, home heating oil, and jet fuel to the State or its citizens and businesses will qualify for inclusion. However, major oil producers and refiners sell petroleum products to independent service stations or through wholesalers/retailers of gasoline, diesel, jet fuel, and home heating oil. Should coal or gas producers that provide coal and fossil gas to out-of-state power plants serving customers in Vermont be included? These boundary definitions are important in setting a workable scope for the project. The objective is not to trace molecules of carbon fuels sold to Vermont consumers but to identify the fossil fuel producers and refiners that have an economic nexus to the State, or are suppliers of carbon fuels to companies that do.

ANR, through its comprehensive research on Vermont's greenhouse gas emissions, can identify many of the qualifying companies.[2] Vermont's State Treasurer can provide relevant information on which fossil fuel producers or refiners have an economic nexus or taxpayer status with the State. It is beyond the scope of the RFI response to define the criteria for determining which potentially "responsible parties" are to be included in the final list. I suggest to start with a provisional list of U.S. and international oil & gas producers or refiners that have retail gas stations in Vermont (Shell, Chevron, Exxon, Valero, Sunoco, etc.), and expand that list to include jet fuel suppliers (BP), home heating oil, natural gas companies (and their suppliers), gas suppliers to regional power plants and gas distributors, and so on. See Appendix Table A-1 for a provisional short list.

3a. Acquiring annual fossil fuel production data

Many published sources compile leading fossil fuel producers and provide at least partial data on annual production by fuel. Especially useful are the historical annual reports by *Oil & Gas Journal* (since ~1980s) and the US EIA *Annual Coal Report.* Bear in mind that most resource-tracking

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[1] Act 122 (§596, 13) defines fossil fuel business as "a business engaging in the extraction of fossil fuels or the refining of petroleum products." As a practical matter, the Act's focus is on large corporate entities, the parent companies, such as ExxonMobil Corp or Shell plc, and not the dozens or 100s of subsidiary companies (e.g., ExxonMobil Kazakhstan Ventures Inc., Imperial Oil Ltd [Canada], or Esso Trading of Abu Dhabi). We do not include or attribute emissions to the thousands of subcontractors that provide oil field services, mining equipment, product transport by pipeline, trucks, marine tankers, or rail companies, bulk fuel storage, or the many fuel distributors to consumers, such as Packard Fuels in Montpelier, VT.

[2] Vermont Agency of Natural Resources (2023) *Vermont GHG Emissions Inventory and Forecast: 1990-2020*, April, 33 pp. https://anr.vermont.gov/content/anr-climate-action-office-releases-annual-greenhouse-gas-emissions-inventory-vermont

publications focus on national and international fossil fuel production by *nations* (e.g., United Nations Statistical Division, and the respected BP *Statistical Review of World Energy* (since 1952, series now transferred to Energy Institute), but provide no data on *company* production. Other datasets include International Energy Agency, World Resources Institute (ClimateWatchData), and the European Commission's Emissions Database for Global Atmospheric Research (EDGAR).[3]

In my experience no single source provides comprehensive data on *company* production of any of the major fossil fuels, especially not historically since 1995 — except for the Carbon Majors dataset discussed below. Even the highly useful *Oil & Gas Journal* OGJ100 and OGJ150 data series that provides oil and gas production data for most domestic and international producers often has to show oil and gas production data as "not available" — especially for state-owned companies.

No single source lists company production across all fossil fuels either by carbon content or energy content (Btus or gigajoules, GJ), and none track companies' diverse production since 1995, as Act 122 requires. Useful, if incomplete, sources include:

Oil & Gas Journal OGJ150 (domestic) and OGJ100 (international).[4] www.ogj.com

World Coal, www.worldcoal.com

BP Energy Statistics / Energy Institute, www.energyinst.org

Global Energy Monitor, https://globalenergymonitor.org

Resource World, https://resourceworld.com/coal-production-update/

National Mining Association *Coal Producer Survey* (active 1990s-~2015; discontinued)

U.S. Energy Information Administration: *Annual Coal Report*, Table 10. Major U.S. Coal Producers, https://www.eia.gov/coal/annual/

U.S. EIA: *US refineries*, 1994-2022: https://www.eia.gov/petroleum/refinerycapacity/archive/

Urgewald, Germany: *2022 Global Coal Exit List: No Transition in Sight*, www.urgewald.org/en/medien/urgewalds-2022-global-coal-exit-list-no-transition-sight

Urgewald: Gogel (*Global Oil & Gas Exit List*): https://gogel.org/about (sign-in required)

One data source merits special mention. CDP (formerly Carbon Disclosure Project; www.cdp.net), accepts submissions from hundreds of companies on climate, energy, water, and so forth. Several dozen oil, gas, and coal companies submit answers to CDP questionnaires on energy production as well as scope 1, 2, and 3 emissions. Company submissions are only from ~2008 forwards, and limited to certain companies and years. CDP membership is required; data access is negotiable.[5]

In addition, other paywall subscriptions have data series on companies and fossil fuel production:[6]

Bloomberg Energy www.bloomberg.com,

IHS Global Insight www.energy.ihs.com,

WoodMacKenzie www.woodmacresearch.com,

Evaluate Energy; https://info.evaluateenergy.com/corporate-financial-operating-data/, and

Rystad Energy (Norway): www.rystadenergy.com.

In sum, publicly available sources report annual production, but none do so consistently for all companies since 1995.

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[3] European Commission, *Emissions Database for Global Atmospheric Rsrch*, https://edgar.jrc.ec.europa.eu/dataset_ghg70 (no charge). >>> International Energy Agency, *Greenhouse Gas Emissions from Energy*, https://www.iea.org/data-and-statistics/data-product/greenhouse-gas-emissions-from-energy. Cost: 640 Euro. >>> United Nations Statistical Division (2021) *Energy Statistics Yearbook*, $90 PDF / $180 print. https://unstats.un.org/unsd/energystats/pubs/yearbook/

[4] Typically in OGJ's September issue.

[5] Katherine Camp, Cities, States, Regions & Public Authorities, CDP, katherine.camp@cdp.net.

[6] I have limited experience with these databases, and cannot evaluate their completeness or accuracy.

It is my opinion that a comprehensive dataset on corporate production of fossil oil, gas, and coal by year since 1995 is best based on original *company-reported* production data in annual reports and SEC 10-K filings; such material disclosure has been required since the U.S. Securities Exchange Act of 1934.[7] The data acquisition process requires downloading these reports at least every third year from 1997 to 2024, because companies typically report three years of financial and operating data. Company-reporting has the advantage of accuracy and completeness. ANR, or its contractor, would copy operational data into a spreadsheet or similar platform for each identified company, convert to annual production by type, and apply the EPA emission factors.[8] See guidance in section 4.

My non-profit institute — Climate Accountability Institute — has collected company-reported production data in its Carbon Majors dataset. That dataset attributed emissions to 100 oil, gas coal, and cement companies.[9] The Carbon Majors dataset will be discussed more fully below.

3b. Acquiring annual fossil fuel refinery output data

As with oil and gas production data, the most reliable and comprehensive data on refinery output is typically reported in company annual reports or SEC 10-Ks. I am not aware of an industry-wide data source that reports petroleum refinery output either in total output or by product type. A refinery dataset by company and each of its refineries is available from the EIA, but this contains data on refinery *capacity*, not utilization rate or output.[10]

Furthermore, some major refining companies are privately-held, such as Koch Industries / Flint Hills LP and Motiva (owned by Saudi Aramco), and privately-held companies are not required to publish actual refinery input, capacity, utilization, or refinery production data. Practically speaking, some integrated oil companies report only refinery capacity or utilization rate, whereas other companies report only partial output data, if at all, for several years from 1995 to 2024.

The paucity of actionable refinery output data can be ameliorated by the State formally requesting refinery data on refinery product output from each of the responsible parties, once that list has been finalized.

4a. Methodology for estimating emissions from production

A robust methodology has to be applied to fossil fuel production data in order to reasonably quantify emissions from production and/or refining and combustion of each carbon fuel by global consumers. Some oil and gas companies have in recent years estimated emissions from sold products — petroleum products and natural gas available for sale — but these are in the minority. Too few of the likely "responsible parties" that have a business nexus with the State of Vermont estimate their scope 3 emissions, and a methodology applicable to the ANR is required.

As stated in Act 122, the State is to estimate emissions attributable to fossil fuel producers using the US EPA "Emission Factor Hub" for specific factors, in the following manner:[11] See Appendix Fig. A-4.

Per million bbl of **crude oil production**:

Eq. 1. CO_2 from combustion: (10.29 $kgCO_2$/gallon) * 42 gal/bbl = 432.18 $kgCO_2$/bbl = 0.432 tCO_2/bbl = 0.432 million tonnes CO_2 per million bbl, or 0.432 $MtCO_2$/Mb.

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[7] 20-F reports for foreign companies, and 40-F reports for Canadian companies that have securities trading in the U.S.

[8] Companies report oil and liquids production in thousand bbl per day, gas in million cubic feet per day, and coal in short tons of metric tonnes per year. See the formulas in section 4.

[9] https://climateaccountability.org/carbon-majors-dataset-2020/

[10] Energy Information Administration (2024) *Refinery Capacity Report 1982-2024*. https://www.eia.gov/petroleum/refinerycapacity/

[11] U.S. Environmental Protection Agency (2024) *Emission Factor Hub for Greenhouse Gas Inventories*, last modified June. https://www.epa.gov/climateleadership/ghg-emission-factors-hub Note: we show EPA data in units commonly reported for oil production (thousand bbl per day * 0.365 = Mb/yr; million cf/day * 0.365 = Bcf/yr; 1.1023 shtons = 1 tonne).

Eq. 2. CH_4: (0.41 gCH_4/gallon) * 42 gal/bbl = (17.22 gCH_4/bbl) * GWP of 28*CO_2 = 0.482 $kgCO_2e$/bbl, or 0.00048 $MtCO_2e$/Mb.

Eq. 3. N_2O: (0.08 gN_2O/gallon) * 42 gal/bbl = (3.36 gN_2O/bbl) * GWP of 265*CO_2 = 0.890 $kgCO_2e$/bbl, or 0.00089 $MtCO_2e$/Mb.

Applying the EPA emission factors for methane and nitrous oxide and converted to CO_2-equivalent from the EPA-reported Global Warming Potential (GWP), each comprise less than 1% of the total emissions for crude oil (0.11% and 0.21%, respectively). Likewise, combustion of natural gas accounts for methane and nitrous oxide of 0.05% and 0.05%, respectively, and for coal methane and nitrous oxide account for 0.32% and 0.45%, respectively. In my opinion, these minor factors are *not material and should be eliminated from computation*.[12] If this recommendation is accepted, we need only refer to emissions CO_2 (not greenhouse gases), and ignore methane and nitrous oxide. If ANR wishes to follow Act 122's inclusion of all EPA combustion-related emissions and include methane and nitrous, the Agency can follow the formulas above.

Thus, for natural gas and coal we only show the formula for CO_2 from combustion:

Per billion cubic feet of **natural gas production** (scf: standard cubic feet, Bcf: billion cubic feet):

Eq. 4. CO_2 from combustion: 0.05444 $kgCO_2$/scf = 0.05444 $MtCO_2$/Bcf.

Per million metric tons (Mt) of **coal production** (utility sector) (EPA $kgCO_2$/short ton [sht]):

Eq. 5. CO_2 from combustion: 1,885 $kgCO_2$/sht = 1.885 $MtCO_2$/Msht/1.1023 sht/t = 1.710 $MtCO_2$/Mt.

4b. Methodology for estimating emissions from refining

A methodology similar to the production-based calculations described above can be applied to each qualified crude oil refiner. The EPA emission factors will be applied to annual refinery output from each responsible party, based on reported categories of petroleum products refined each year. These data are reported, when reported, in company annual reports and SEC 10-K filings.

Common reported refined petroleum products include, and the EPA emission factor for each:

Motor gasoline	8.78 $kgCO_2$/gallon	=	0.36876 $MtCO_2$/Mb
Diesel (distillate) fuel	10.21 $kgCO_2$/gallon	=	0.42882 $MtCO_2$/Mb
Jet fuel	9.75 $kgCO_2$/gallon	=	0.40950 $MtCO_2$/Mb
Heating oil	10.21 $kgCO_2$/gallon	=	0.42882 $MtCO_2$/Mb
Crude Oil	10.29 $kgCO_2$/gallon	=	0.43218 $MtCO_2$/Mb

In addition, most oil & gas companies report a basket of "lubricants, specialty, and other petroleum products," an ill-defined category that may (or may not) include products intended for combustion, such as petroleum coke, propane, or aviation fuel. These "other products" range from ~8% to 15% of total refinery output, of which an unknown percentage is for combustion products. In theory, estimating emissions from company refinery output is straightforward. However, it is likely to under-estimate emissions due to the obscurity and lack of detail on the "other refinery products."

Alternatively, ANR could estimate emissions from refinery output on the basis of *crude oil inputs* to its refineries, but would then need to account for refinery production of petrochemical feedstocks, road oil, lubricants, and other non-energy uses. The percentage of non-energy products vary by season, by company, and by refinery.

[12] These small factors are not from upstream or mid-stream emissions from production or refining, which are substantial, and exclude scope 1 operational emissions. EPA footnote: "The factors represented in the table above represent combustion emissions only and do not represent upstream emissions."

4c. Combining estimated emissions from production and refining

Many of the companies on the list of responsible parties will be both producers *and* refiners of crude oil. This analyst assumes that the State will want to develop datasets on emissions from both production and refining for each year from 1995 to 2024, and to count only the higher value for each year so as to avoid double-counting. This concerns crude oil production and refining only: natural gas is typically reported by companies as "gas available for sale" — in other words, post-processing of raw gas into marketable gas. A preliminary view of two companies' production-based and refinery-based emissions are in Appendix Figures A-6 (Chevron) and A-7 (ExxonMobil).

Oil and gas majors also owned or acquired coal-producing assets, including Chevron (1965-2012), BP (1960-1989), ExxonMobil (1970-2002), and Shell (1979-1999). It is my opinion that emissions from coal production for the salient years 1995-forward should be included.

5. Determining applicable shares of global emissions

In order to "determine their applicable share of covered greenhouse gas emissions for the covered period from 1995 to 2024" one needs to compare product-related or refined product emissions for each company to global fossil fuel emissions over the same "covered period." The gold standard historical record of global carbon content of fossil fuel production and emissions upon combustion of fossil fuels is the CDIAC / GCB database, which permits calculation of each entity's share of covered global greenhouse gas emissions for 1995-2024.[13] A more limited alternative dataset of historical global CO_2 emissions is available from the European Commission EDGAR website.[14]

As a preliminary note, the CDIAC / GCB data for global combustion of oil, gas, and coal for 1995-2022 totals 825 $GtCO_2$; adding global oil, gas, and coal emissions for 2023-2024 will add ~35 $GtCO_2$ per year, thus a 1995-2024 total of ~896 $GtCO_2$.

6. Determining applicable shares of Vermont climate damages

The Act defines how to calculate each responsible party's share of certain global emissions and the share of the cost to the State of Vermont, i.e., the same ratio for each party's emissions and costs:

> **(§ 598, b):** *With respect to each responsible party, the cost recovery demand shall be equal to an amount that bears the same ratio to the cost to the State of Vermont and its residents, as calculated by the State Treasurer pursuant to section 599c of this title, from the emission of covered greenhouse gases during the covered period as the responsible party's applicable share of covered greenhouse gas emissions bears to the aggregate applicable shares of covered greenhouse gas emissions resulting from the use of fossil fuels extracted or refined during the covered period*.

Therefore, for each fossil fuel producer and/or refiner, the attributed emissions using the formulas above for each fuel produced over the covered period from 1995 to 2024 is to be divided by the total global emissions from the combustion of fossil fuels over the same period. This excludes emissions from cement production, and of flaring emissions from production and processing of crude oil and natural gas.

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[13] Boden, Tom, Bob Andres, & Gregg Marland (2017) *Global CO_2 Emissions from Fossil-Fuel Burning, Cement Manufacture, and Gas Flaring: 1751-2014*. Carbon Dioxide Information Analysis Center, Oak Ridge National Lab., US Dept of Energy, Oak Ridge TN. This dataset has been updated by Global Carbon Budget (Univ Exeter, under the auspices of the Global Carbon Project, www.globalcarbonproject.org): Friedlingstein, Pierre, et al. (2023) Global Carbon Budget 2023, Global Carbon Budget, *Earth Syst. Sci. Data*, vol. 15:5301–5369, https://essd.copernicus.org/articles/15/5301/2023/

Note: this dataset covers fossil fuel solids, liquids, and gases, as well as carbon content of flaring and process emissions from cement production; in all, these are referred to as "industrial emissions" and exclude anthropogenic emissions from deforestation, soil carbon, other carbon cycle "interferences," and also exclude non-energy methane [rice fields, animal husbandry, landfills], nitrous oxide, and F-gases.

[14] European Commission (2023) *Global Greenhouse Gas Emissions, EDGAR v8.0*. details CO_2 emissions for every country, https://edgar.jrc.ec.europa.eu/dataset_ghg80 but the dataset lacks summation of global emissions and dataset begins in 1970-forward. Archived previous versions summed global emissions for fossil fuel CO_2 and methane.

As an example, using the Carbon Majors results, Chevron's production-related emissions from 1995 to 2022 are ~7.21 $GtCO_2$ for oil, ~3.25 $GtCO_2$ for gas, and ~0.43 $GtCO_2$ for coal. Chevron's share is 10.9 $GtCO_2$ / 825 $GtCO_2$ = 1.32% of global fossil fuel emissions. (ANR's calculation will differ once updated.)[15] This percentage can be applied to cost recovery demands from each responsible party.

Carbon Majors database: a source of publicly available fossil fuel production data

To my knowledge the only comprehensive historical database of fossil fuel production by fossil fuel producing *companies* (both investor-owned and state-owned) is the Carbon Majors database compiled by the Climate Accountability Institute. A pioneering peer-reviewed scientific paper presenting the methods and results was published in 2014.[16]

In brief, the Carbon Majors methodology identifies fossil fuel producers with production that meets the threshold of ~8 million tonnes carbon (MtC) in a recent year, acquires historical production data from each entity's SEC 10-K filings or its Annual Report or third-party sources from as early as available on production of crude oil (including condensate and natural gas liquids), natural gas, and coal (by rank or carbon content). Individual worksheets were prepared for each producing entity for data entry on production for each fuel: crude oil in thousand bbl/day, natural gas in million cubic feet/day, and coal in metric tonnes (or short tons) per year. These were converted to million bbl/year (Mb), billion cubic feet/year (Bcf), and million tonnes (Mt). Emissions factors per Mb, Bcf, and Mt were modified from international standards (IPCC, EPA, API) in order to account for net non-energy uses of each fuel, such as crude oil sequestered in petrochemicals, road oil, and lubricants (~8.0% of production), natural gas to produce fertilizers (~1.9%), and minor quantities of coal used for pigments and carbon fiber (~0.02%).

The Carbon Majors database identifies all of the world's largest producers of oil, gas, and coal, and include all of the companies that have a business nexus with Vermont *and* have cumulative production-related emissions exceeding 1 $GtCO_2$. The database also estimates scope 1 operational emissions —including emissions from flaring, CO_2 from gas processing, own fuel use, and leaked and fugitive methane — which Vermont's Act 122 excludes in favor of its more direct methodology of production times EPA emission factors for each fossil fuel.

The Carbon Majors fossil fuel production dataset can be shared with Vermont's Agency of Natural Resources. Climate Accountability Institute (CAI) has posted fossil fuel production for 100 state-owned and investor-owned oil, gas, coal, and cement companies up to the year 2020.[17] CAI has updated data to 2022, which I am personally happy to share with ANR.

In addition, CAI has transferred all future updating of the Carbon Majors database to InfluenceMap (London), and they will be able to share data with ANR as well.[18]

Regarding refinery emissions, CAI's gathering of data on refinery output and associated emissions is neither comprehensive nor historically complete (company reporting, as discussed above, is variable). The institute has established a methodology but the results are in development.

Respectfully,

Richard Heede

Director, Climate Accountability Institute.

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[15] As discussed below, the Carbon Majors methodology includes scope 1 operational emissions such as CO_2 emissions from own fuel use, natural gas processing, and flaring.

[16] 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

[17] https://climateaccountability.org/carbon-majors-dataset-2020/

[18] InfluenceMap (2024) *The Carbon Majors Database Launch Rpt*, April. http://influencemap.org & https://carbonmajors.org

Appendix

The methodology and math, in brief

The sequence and summary of calculations

1. Gather data on company production of crude oil (and condensate and natural gas liquids), natural gas (often reported as "gas available for sale"); and coal for each year 1995 to 2024. Use company *Annual Reports* or SEC Form 10-K (US companies), 20-F (Canadian), or 40-F (international); account for mergers and acquisitions over the period 1995 to 2024;
2. Create worksheet for each entity, enter data in clearly-marked columns, using standard units, convert daily production into annual production, cite data sources in cell notes; show the math (which facilitates verification of the results);
3. Multiply annual production of crude oil and liquids in million bbl/yr by the EPA Emission Factor of 0.432 $MtCO_2$/Mb. Use the formula in Eq. 1 above;
4. Multiply annual production of natural gas, in billion cubic feet per year (Bcf) by the EPA Emission Factor 0.05444 $MtCO_2$/Bcf. Use the formula in Eq. 4;
5. Multiply annual production of coal, in million metric tonnes, by the EPA Emission Factor 1.710 $MtCO_2$/Mt. Use the formula in Eq. 5;
6. Results should be shown in million tonnes CO_2 ($MtCO_2$) per year, by fuel, for each entity;
7. Exclude companies whose total emissions exceed 1 GtCO2 over the covered period 1995-2024.

Calculations for refinery output emissions

8. Gather data on refinery output (aka "outturn") by refined petroleum products, for each entity;
9. Convert daily refinery output to annual output, by petroleum product;
10. Multiply annual refinery output of each petroleum product by the corresponding EPA emission factor (see page 5) in $MtCO_2$ per million bbl ($MtCO_2$/Mb);
11. Sum annual emissions by petroleum product for each entity.
12. Alternate: if refiner only reports "crude oil input to refineries" then estimate emissions by using the crude oil emission factor (table p. 5) but account for typical non-combusted/sequestered "other and specialty products" of 14.3% by reducing the EF from 0.43218 * (1-0.143) = 0.37038 $MtCO_2$/Mb.[19]

Calculate net emissions from crude oil and liquids production to emission from refining output

13. Compare product-related emissions to refinery output emissions, show the larger result;
14. Count only the larger quantity for each year 1995 to 2024.

Add emissions from natural gas production and coal production to petroleum emissions

15. Add natural gas and coal emissions to the larger of emissions from oil production or refining emissions for each entity from 1995 to 2024.

Calculate global fossil fuel emissions 1995-2024 and the share of each responsible party

16. Calculate sum of all global oil, gas, and coal emissions from the CDIAC / GCB dataset referenced above for 1995 to 2024.
17. Determine the share of each "responsible party's" emissions as a percent of global fossil fuel emissions 1995-2024.
18. Apply these factors to the determined climate damages estimated by Vermont's Treasurer.

[19] Analysis of average "other and specialty products" (all presumed non-combusted) of BP, Chevron, ExxonMobil, Shell, and TotalEnergies, various years 1995-2022 by Climate Accountability Institute.

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Figure A-1. *Preliminary* list of all Carbon Major entities whose attributed emissions, including operational scope 1 emissions of CO_2 and methane, exceed 1 $GtCO_2e$ from 1995 to 2022.[20]

				Richard Heede Climate Accountability Institute 3-Apr-24	
	Global Fossil Fuel & Cement CO2 + CH4	950,196	MtCO2e		
				Global FF/Global GHG	70.37%
	1995-2022	MtCO2 & MtCH4 MtCO2e	data range	% global FF % of global FF	% global GHG % of global GHG
1	Saudi Aramco, Saudi Arabia	45,548	2022	4.79%	3.37%
2	Gazprom, Russia	40,521	2022	4.26%	3.00%
3	National Iranian Oil Co.	25,512	2022	2.68%	1.89%
4	Coal India, India	23,437	2022	2.47%	1.74%
5	ExxonMobil, USA	18,092	2022	1.90%	1.34%
6	Royal Dutch Shell, The Netherlands	16,485	2022	1.73%	1.22%
7	PetroChina, China	15,372	2022	1.62%	1.14%
8	Petroleos Mexicanos (Pemex)	15,109	2022	1.59%	1.12%
9	BP, UK	14,609	2022	1.54%	1.08%
10	Chevron, USA	13,430	2022	1.41%	0.99%
11	Abu Dhabi, United Arab Emirates	13,418	2022	1.41%	0.99%
12	Peabody Energy, USA	12,064	2022	1.27%	0.89%
13	Rosneft, Russian Federation	10,979	2022	1.16%	0.81%
14	Petroleos de Venezuela (PDVSA)	10,600	2022	1.12%	0.78%
15	Sonatrach, Algeria	10,402	2022	1.09%	0.77%
16	Kuwait Petroleum Corp., Kuwait	10,350	2022	1.09%	0.77%
17	TotalEnergies, France	10,060	2022	1.06%	0.74%
18	Iraq National Oil Co., Iraq	9,355	2022	0.98%	0.69%
19	Petroleo Brasileiro (Petrobras), Brazil	9,034	2022	0.95%	0.67%
20	BHP Billiton, Australia	8,430	2022	0.89%	0.62%
21	ConocoPhillips, USA	8,154	2022	0.86%	0.60%
22	Lukoil, Russia	7,808	2022	0.82%	0.58%
23	Petronas, Malaysia	7,455	2022	0.78%	0.55%
24	Qatar Petroleum, Qatar	7,158	2022	0.75%	0.53%
25	Nigerian National Petroleum, Nigeria	7,117	2022	0.75%	0.53%
26	Equinor, Norway	6,694	2022	0.70%	0.50%
27	ENI, Italy	6,364	2022	0.67%	0.47%
28	Glencore, Switzerland	6,286	2022	0.66%	0.47%
29	Arch Resources, USA	5,691	2022	0.60%	0.42%
30	Alpha Met / Contura Energy, USA	5,485	2022	0.58%	0.41%
31	Rio Tinto, UK	5,285	2019 divest	0.56%	0.39%
32	Occidental, USA	5,136	2022	0.54%	0.38%
33	Anglo American, UK	5,108	2022	0.54%	0.38%
34	Repsol, Spain	4,499	2022	0.47%	0.33%
35	Libya National Oil Corp., Libya	4,057	2022	0.43%	0.30%
36	Sinopec, China	3,915	2018	0.41%	0.29%
37	CNOOC (China National Offshore Oil Co.)	3,910	2022	0.41%	0.29%
38	Pertamina, Indonesia	3,721	2022	0.39%	0.28%
39	Petoro. Norway	3,583	2018	0.38%	0.27%
40	Oil & Gas Corp India, India	3,516	2018	0.37%	0.26%
41	CONSOL Energy, USA	3,503	2022	0.37%	0.26%
42	RWE, Germany	3,403	2022	0.36%	0.25%
43	Suncor, Canada	3,358	2018	0.35%	0.25%
44	Sasol, South Africa	3,328	2022	0.35%	0.25%
45	Novatek, Russian Federation	3,097	2018	0.33%	0.23%
46	TurkmenGaz, Turkmenistan	2,915	2018	0.31%	0.22%
47	Sonangol, Angola	2,852	2022	0.30%	0.21%
48	Petroleum Development Oman	2,675	2018	0.28%	0.20%
49	Canadian Natural Resources, Canada	2,614	2022	0.28%	0.19%
50	Egyptian General Petroleum, Egypt	2,590	2018	0.27%	0.19%
51	Devon Energy, USA	2,564	2018	0.27%	0.19%
52	Ecopetrol, Colombia	2,561	2018	0.27%	0.19%
53	Holcim, Switzerland	2,522	2018	0.27%	0.19%
54	Singareni Collieries Company, India	2,506	2018	0.26%	0.19%
55	Exxaro, South Africa	2,174	2022	0.23%	0.16%
56	Murray Coal Corporation, USA	2,165	2022	0.23%	0.16%
57	EnCana, Canada	2,030	2018	0.21%	0.15%
58	Apache, USA	1,892	2022	0.20%	0.14%
59	Alliance, USA	1,778	2022	0.19%	0.13%
60	EOG Resources, USA	1,733	2018	0.18%	0.13%
61	Navajo Cloud Peak	1,688	2021	0.18%	0.13%
62	Marathon, USA	1,682	2022	0.18%	0.12%
63	Chesapeake Energy, USA	1,536	2022	0.16%	0.11%
64	Hess, USA	1,497	2022	0.16%	0.11%
65	PetroEcuador	1,436	2018	0.15%	0.11%
66	Bahrain Petroleum Corp.	1,299	2022	0.14%	0.10%
67	Teck Resources, Canada	1,289	2018	0.14%	0.10%
68	HeidelbergCement, Germany	1,253	2018	0.13%	0.09%
69	Husky, Canada	1,243	2022	0.13%	0.09%
70	Westmoreland, USA	1,197	2018	0.13%	0.09%
71	North American Coal, USA	1,088	2022	0.11%	0.08%
72	Wintershall, Germany	1,002	2018	0.11%	0.07%

[20] This list includes production-based emissions only, and excludes refining companies such as Koch/Flint Hills and Valero, both of which likely exceed 1 $GtCO_2$ for 1995-2024.

Carbon Majors list of emissions attributable to oil and gas producers that exceed 1 $GtCO_2$ from 1995 to 2022.[21]

The tables below list the entities shown in Figure A-1 after potentially responsible parties that are unlikely to meet the economic nexus with Vermont requirement are removed. A number of the companies listed in Table A-2 are potential additional "responsible parties" in Table A-1. Emissions attributed to each entity in million tonnes CO_2.

Table A-1. List of highly likely "responsible parties," in $MtCO_2$

ExxonMobil, USA (Exxon and Mobil)	18,092
Shell, UK	16,485
BP, UK	14,609
Chevron, USA (also Texaco)	13,430
Valero, USA	na
Sunoco, USA	na
Citgo (PDVSA)	na
Add companies that supply fossil gas to Vermont Gas Systems Inc.	
Add companies that supply gas or coal to regional (not in-state) power plants?	

Table A-2. List of potential additional "responsible parties," in $MtCO_2$

Saudi Aramco, Saudi Arabia	45,548
Petroleos Mexicanos (Pemex)	15,109
Peabody Energy, USA	12,064
Citgo / Petroleos de Venezuela (PDVSA)	10,600
TotalEnergies, France	10,060
ConocoPhillips, USA	8,154
Equinor, Norway	6,694
ENI, Italy	6,364
Arch Resources, USA	5,691
Alpha Met / Contura Energy, USA	5,485
Occidental, USA	5,136
Devon Energy, USA	2,564
Murray Coal Corporation, USA	2,165
Ovintiv (EnCana), Canada	2,030
Apache, USA	1,892
Alliance, USA	1,778
EOG Resources, USA	1,733
CONSOL Energy, USA	3,503
Suncor, Canada	3,358
Marathon Oil Corp., USA	1,682
Chesapeake Energy, USA	1,536
Hess, USA	1,497
North American Coal, USA	1,088
Koch Industries / Flint Hills LP	na
Marathon Petroleum (refining)	na
Motiva (Saudi Aramco)	na

[21] The Carbon Majors methodology includes scope 1 operational emissions from fugitive methane and CO_2 from own fuel use, flaring, and vented CO_2, and also deduct for net non-energy uses of each fuel. The attributed emissions are thus somewhat higher than the methodology specified in Act 122, as are the global emissions.

Figure A-2. Carbon Majors' coal production data for Peabody Energy, 1945-2022.[22]

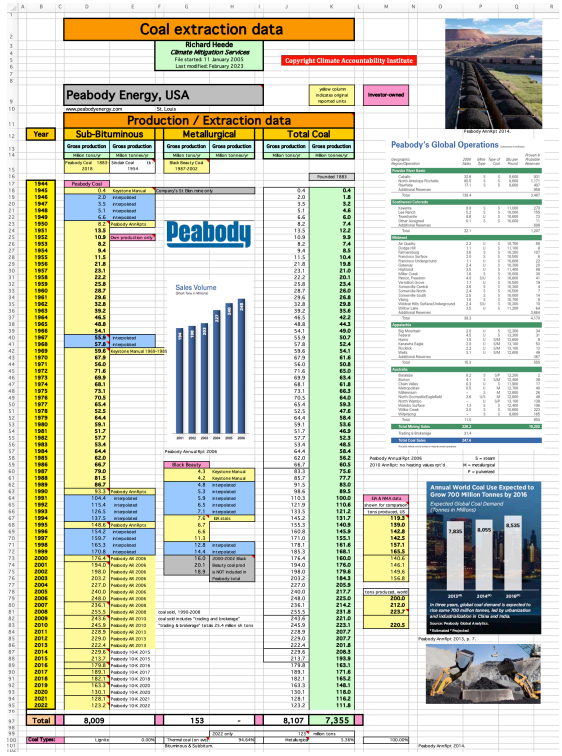
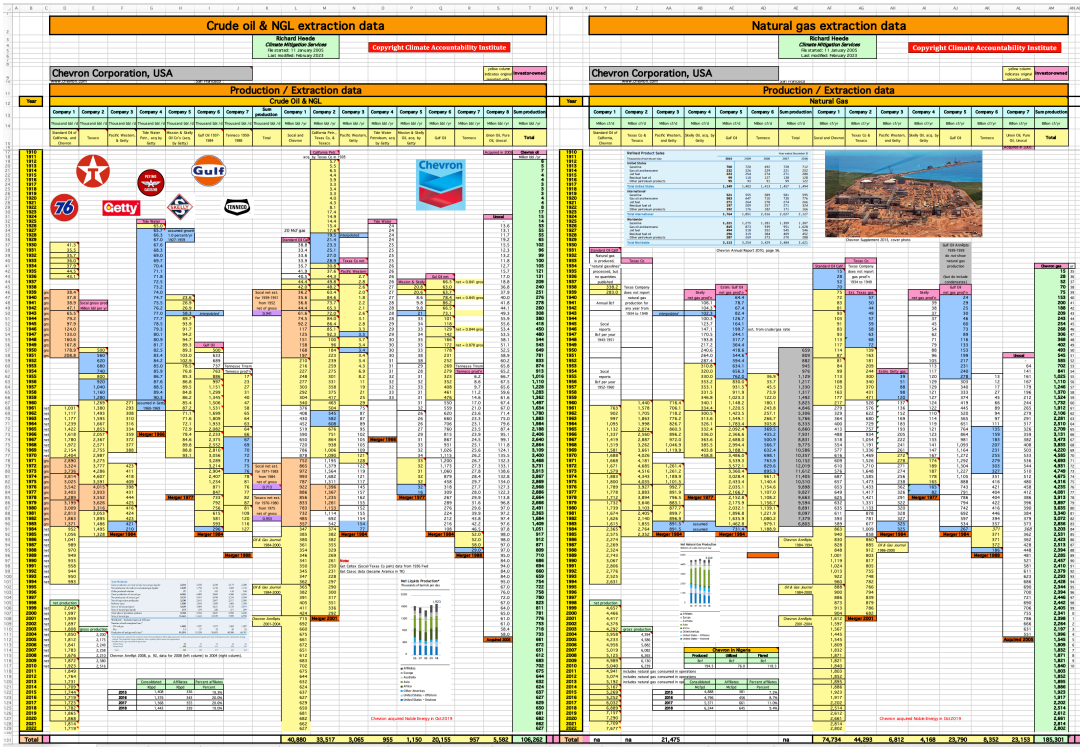


Figure A-3. Carbon Majors' oil & gas production data for Chevron, 1912-2022. The green columns sum annual production of oil (left) and gas (right), including mergers & acquisitions.



[22] Full PDF versions available at: https://climateaccountability.org/carbon-majors-dataset-2020/

Figure A-4. US EPA emission factors referenced in Act 122.[23]

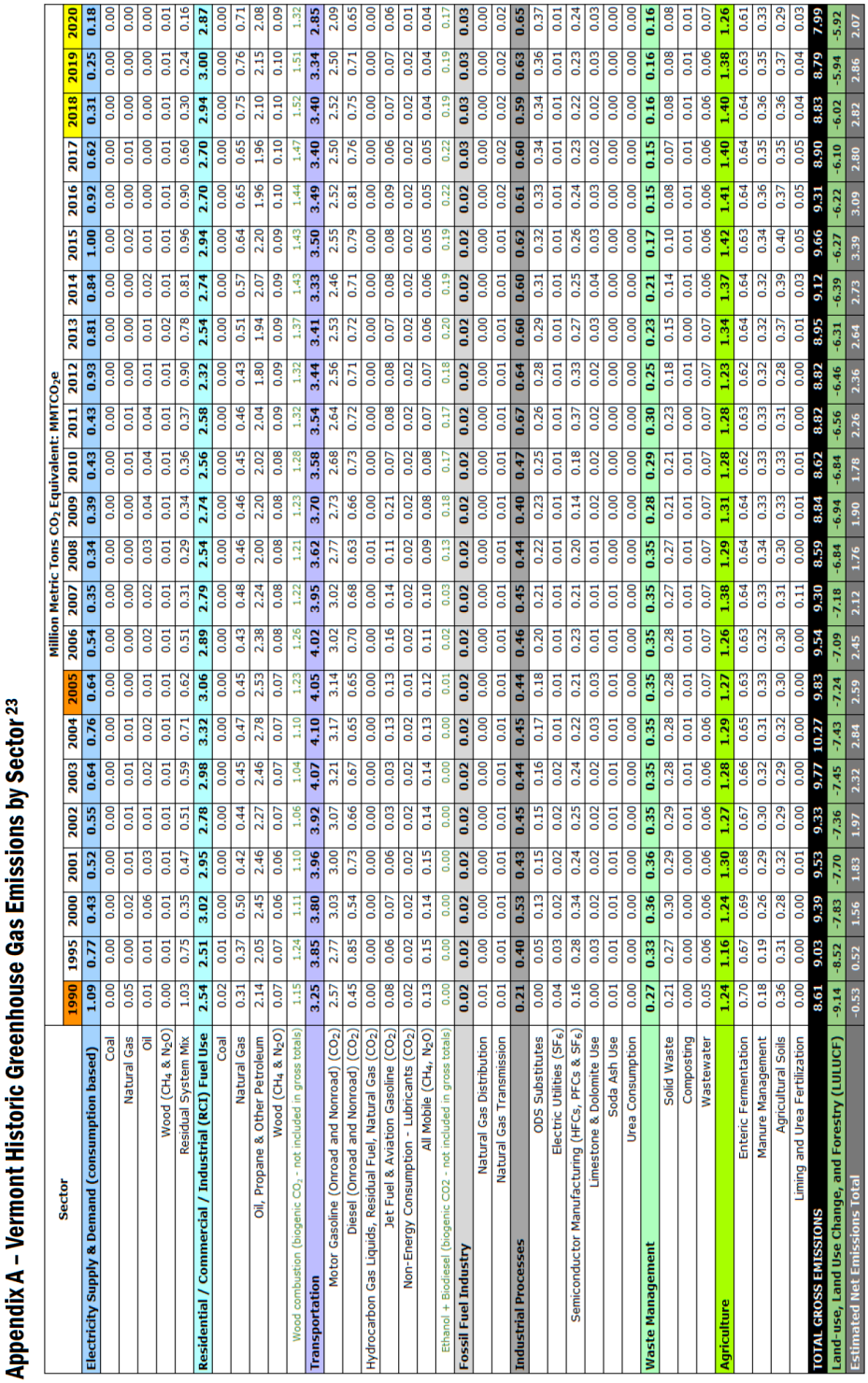
Fuel Type	Heat Content (HHV)	CO_2 Factor	CH_4 Factor	N_2O Factor	CO_2 Factor	CH_4 Factor	N_2O Factor
	mmBtu per short ton	kg CO_2 per mmBtu	g CH_4 per mmBtu	g N_2O per mmBtu	kg CO_2 per short ton	g CH_4 per short ton	g N_2O per short ton
Coal and Coke							
Anthracite	25.09	103.69	11	1.6	2,602	276	40
Bituminous	24.93	93.28	11	1.6	2,325	274	40
Sub-bituminous	17.25	97.17	11	1.6	1,676	190	28
Lignite	14.21	97.72	11	1.6	1,389	156	23
Mixed (Commercial Sector)	21.39	94.27	11	1.6	2,016	235	34
Mixed (Electric Power Sector)	19.73	95.52	11	1.6	1,885	217	32
Mixed (Industrial Coking)	26.28	93.90	11	1.6	2,468	289	42
Mixed (Industrial Sector)	22.35	94.67	11	1.6	2,116	246	36
Coal Coke	24.80	113.67	11	1.6	2,819	273	40
Other Fuels - Solid							
Municipal Solid Waste	9.95	90.70	32	4.2	902	318	42
Petroleum Coke (Solid)	30.00	102.41	32	4.2	3,072	960	126
Plastics	38.00	75.00	32	4.2	2,850	1,216	160
Tires	28.00	85.97	32	4.2	2,407	896	118
Biomass Fuels - Solid							
Agricultural Byproducts	8.25	118.17	32	4.2	975	264	35
Peat	8.00	111.84	32	4.2	895	256	34
Solid Byproducts	10.39	105.51	32	4.2	1,096	332	44
Wood and Wood Residuals	17.48	93.80	7.2	3.6	1,640	126	63
	mmBtu per scf	kg CO_2 per mmBtu	g CH_4 per mmBtu	g N_2O per mmBtu	kg CO_2 per scf	g CH_4 per scf	g N_2O per scf
Natural Gas							
Natural Gas	0.001026	53.06	1.0	0.10	0.05444	0.00103	0.00010
Other Fuels - Gaseous							
Blast Furnace Gas	0.000092	274.32	0.022	0.10	0.02524	0.000002	0.000009
Coke Oven Gas	0.000599	46.85	0.48	0.10	0.02806	0.000288	0.000060
Fuel Gas	0.001388	59.00	3.0	0.60	0.08189	0.004164	0.000833
Propane Gas	0.002516	61.46	3.0	0.60	0.15463	0.007548	0.001510
Biomass Fuels - Gaseous							
Landfill Gas	0.000485	52.07	3.2	0.63	0.025254	0.001552	0.000306
Other Biomass Gases	0.000655	52.07	3.2	0.63	0.034106	0.002096	0.000413
	mmBtu per gallon	kg CO_2 per mmBtu	g CH_4 per mmBtu	g N_2O per mmBtu	kg CO_2 per gallon	g CH_4 per gallon	g N_2O per gallon
Petroleum Products							
Asphalt and Road Oil	0.158	75.36	3.0	0.60	11.91	0.47	0.09
Aviation Gasoline	0.120	69.25	3.0	0.60	8.31	0.36	0.07
Butane	0.103	64.77	3.0	0.60	6.67	0.31	0.06
Butylene	0.105	68.72	3.0	0.60	7.22	0.32	0.06
Crude Oil	0.138	74.54	3.0	0.60	10.29	0.41	0.08
Distillate Fuel Oil No. 1	0.139	73.25	3.0	0.60	10.18	0.42	0.08
Distillate Fuel Oil No. 2	0.138	73.96	3.0	0.60	10.21	0.41	0.08
Distillate Fuel Oil No. 4	0.146	75.04	3.0	0.60	10.96	0.44	0.09
Ethane	0.068	59.60	3.0	0.60	4.05	0.20	0.04
Ethylene	0.058	65.96	3.0	0.60	3.83	0.17	0.03
Heavy Gas Oils	0.148	74.92	3.0	0.60	11.09	0.44	0.09
Isobutane	0.099	64.94	3.0	0.60	6.43	0.30	0.06
Isobutylene	0.103	68.86	3.0	0.60	7.09	0.31	0.06
Kerosene	0.135	75.20	3.0	0.60	10.15	0.41	0.08
Kerosene-Type Jet Fuel	0.135	72.22	3.0	0.60	9.75	0.41	0.08
Liquefied Petroleum Gases (LPG)	0.092	61.71	3.0	0.60	5.68	0.28	0.06
Lubricants	0.144	74.27	3.0	0.60	10.69	0.43	0.09
Motor Gasoline	0.125	70.22	3.0	0.60	8.78	0.38	0.08
Naphtha (<401 deg F)	0.125	68.02	3.0	0.60	8.50	0.38	0.08
Natural Gasoline	0.110	66.88	3.0	0.60	7.36	0.33	0.07
Other Oil (>401 deg F)	0.139	76.22	3.0	0.60	10.59	0.42	0.08
Pentanes Plus	0.110	70.02	3.0	0.60	7.70	0.33	0.07
Petrochemical Feedstocks	0.125	71.02	3.0	0.60	8.88	0.38	0.08
Propane	0.091	62.87	3.0	0.60	5.72	0.27	0.05
Propylene	0.091	67.77	3.0	0.60	6.17	0.27	0.05
Residual Fuel Oil No. 5	0.140	72.93	3.0	0.60	10.21	0.42	0.08
Residual Fuel Oil No. 6	0.150	75.10	3.0	0.60	11.27	0.45	0.09
Special Naphtha	0.125	72.34	3.0	0.60	9.04	0.38	0.08
Unfinished Oils	0.139	74.54	3.0	0.60	10.36	0.42	0.08
Used Oil	0.138	74.00	3.0	0.60	10.21	0.41	0.08

Gas	100-Year GWP
CH_4	28
N_2O	265

Source: Intergovernmental Panel on Climate Change (IPCC), Fifth Assessment Report (AR5), 2013. See the source note to Table 11 for further explanation.

[23] [23] U.S. Environmental Protection Agency (2024) *Emission Factor Hub for Greenhouse Gas Inventories,* last modified June. https://www.epa.gov/climateleadership/ghg-emission-factors-hub

Figure A-5. Vermont Historic Greenhouse Gas Emissions by Sector, 1990-2020.[24]



Appendix A – Vermont Historic Greenhouse Gas Emissions by Sector[23]

Million Metric Tons CO_2 Equivalent: MMTCO$_2$e

Sector	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Electricity Supply & Demand (consumption based)	1.09	0.77	0.43	0.52	0.55	0.64	0.76	0.64	0.54	0.35	0.34	0.39	0.43	0.43	0.93	0.81	0.84	1.00	0.92	0.62	0.31	0.25	0.18
Coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural Gas	0.05	0.00	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00
Oil	0.01	0.01	0.06	0.03	0.01	0.02	0.02	0.01	0.02	0.02	0.03	0.04	0.04	0.04	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00
Wood (CH_4 & N_2O)	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Residual System Mix	1.03	0.75	0.35	0.47	0.51	0.59	0.71	0.62	0.51	0.31	0.29	0.34	0.36	0.37	0.90	0.78	0.81	0.96	0.90	0.60	0.30	0.24	0.16
Residential / Commercial / Industrial (RCI) Fuel Use	2.54	2.51	3.02	2.95	2.78	2.98	3.32	3.06	2.89	2.79	2.54	2.74	2.56	2.58	2.32	2.54	2.74	2.94	2.70	2.70	2.94	3.00	2.87
Coal	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural Gas	0.31	0.37	0.50	0.42	0.44	0.45	0.47	0.45	0.43	0.48	0.46	0.46	0.45	0.46	0.43	0.51	0.57	0.64	0.65	0.65	0.75	0.76	0.71
Oil, Propane & Other Petroleum	2.14	2.05	2.45	2.46	2.27	2.46	2.78	2.53	2.38	2.24	2.00	2.20	2.02	2.04	1.80	1.94	2.07	2.20	1.96	1.96	2.10	2.15	2.08
Wood (CH_4 & N_2O)	0.07	0.07	0.06	0.06	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.09
Wood combustion (biogenic CO_2 - not included in gross totals)	1.15	1.24	1.11	1.10	1.06	1.04	1.10	1.23	1.26	1.22	1.21	1.23	1.28	1.28	1.32	1.32	1.37	1.43	1.43	1.44	1.47	1.52	1.51	1.32
Transportation	3.25	3.85	3.80	3.96	3.92	4.07	4.10	4.05	4.02	3.95	3.62	3.70	3.58	3.54	3.44	3.41	3.33	3.50	3.49	3.40	3.40	3.34	2.85
Motor Gasoline (Onroad and Nonroad) (CO_2)	2.57	2.77	3.03	3.00	3.07	3.21	3.17	3.14	3.02	3.02	2.77	2.73	2.68	2.64	2.56	2.53	2.46	2.55	2.52	2.50	2.52	2.50	2.09
Diesel (Onroad and Nonroad) (CO_2)	0.45	0.85	0.54	0.73	0.66	0.67	0.65	0.65	0.70	0.68	0.63	0.66	0.73	0.72	0.71	0.72	0.71	0.79	0.81	0.76	0.75	0.71	0.65
Hydrocarbon Gas Liquids, Residual Fuel, Natural Gas (CO_2)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jet Fuel & Aviation Gasoline (CO_2)	0.08	0.06	0.07	0.06	0.03	0.03	0.13	0.13	0.16	0.14	0.11	0.21	0.07	0.08	0.08	0.07	0.08	0.08	0.09	0.06	0.07	0.07	0.06
Non-Energy Consumption - Lubricants (CO_2)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
All Mobile (CH_4, N_2O)	0.13	0.15	0.14	0.15	0.14	0.14	0.13	0.12	0.11	0.10	0.09	0.08	0.08	0.07	0.07	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.04
Ethanol + Biodiesel (biogenic CO2 - not included in gross totals)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.13	0.18	0.17	0.17	0.18	0.20	0.19	0.19	0.22	0.22	0.19	0.19	0.17
Fossil Fuel Industry	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03
Natural Gas Distribution	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural Gas Transmission	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02
Industrial Processes	0.21	0.40	0.53	0.43	0.45	0.44	0.45	0.44	0.46	0.45	0.44	0.40	0.47	0.67	0.64	0.60	0.60	0.62	0.61	0.60	0.59	0.63	0.65
ODS Substitutes	0.00	0.05	0.13	0.15	0.15	0.16	0.17	0.18	0.20	0.21	0.22	0.23	0.25	0.26	0.28	0.29	0.31	0.32	0.33	0.34	0.34	0.36	0.37
Electric Utilities (SF_6)	0.04	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Semiconductor Manufacturing (HFCs, PFCs & SF_6)	0.16	0.28	0.34	0.24	0.25	0.24	0.22	0.21	0.23	0.21	0.20	0.14	0.18	0.37	0.33	0.27	0.25	0.26	0.24	0.23	0.22	0.23	0.24
Limestone & Dolomite Use	0.00	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.04	0.03	0.03	0.02	0.02	0.03	0.03
Soda Ash Use	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Urea Consumption	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Waste Management	0.27	0.33	0.36	0.36	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.28	0.29	0.30	0.25	0.23	0.21	0.17	0.15	0.15	0.16	0.16	0.16
Solid Waste	0.21	0.27	0.30	0.29	0.29	0.28	0.28	0.28	0.28	0.27	0.27	0.21	0.21	0.23	0.18	0.15	0.14	0.10	0.08	0.07	0.08	0.08	0.08
Composting	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Wastewater	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.07
Agriculture	1.24	1.16	1.24	1.30	1.27	1.28	1.29	1.27	1.26	1.38	1.29	1.31	1.28	1.28	1.23	1.34	1.37	1.42	1.41	1.40	1.40	1.38	1.26
Enteric Fermentation	0.70	0.67	0.69	0.68	0.67	0.66	0.65	0.63	0.63	0.64	0.64	0.64	0.62	0.63	0.62	0.64	0.64	0.63	0.64	0.64	0.64	0.63	0.61
Manure Management	0.18	0.19	0.26	0.29	0.30	0.32	0.31	0.33	0.32	0.33	0.34	0.33	0.33	0.33	0.32	0.32	0.32	0.34	0.36	0.35	0.36	0.35	0.33
Agricultural Soils	0.36	0.31	0.28	0.32	0.29	0.29	0.32	0.30	0.30	0.31	0.30	0.33	0.33	0.31	0.28	0.37	0.39	0.40	0.37	0.35	0.36	0.37	0.29
Liming and Urea Fertilization	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.01	0.01	0.00	0.00	0.01	0.03	0.05	0.05	0.05	0.04	0.04	0.03
TOTAL GROSS EMISSIONS	8.61	9.03	9.39	9.53	9.33	9.77	10.27	9.83	9.54	9.30	8.59	8.84	8.62	8.82	8.82	8.95	9.12	9.66	9.31	8.90	8.83	8.79	7.99
Land-use, Land Use Change, and Forestry (LULUCF)	-9.14	-8.52	-7.83	-7.70	-7.36	-7.45	-7.43	-7.24	-7.09	-7.18	-6.84	-6.94	-6.84	-6.56	-6.46	-6.31	-6.39	-6.27	-6.22	-6.10	-6.02	-5.94	-5.92
Estimated Net Emissions Total	-0.53	0.52	1.56	1.83	1.97	2.32	2.84	2.59	2.45	2.12	1.76	1.90	1.78	2.26	2.36	2.64	2.73	3.39	3.09	2.80	2.82	2.86	2.07

[24] Vermont Agency of Natural Resources (2023) *Vermont GHG Emissions Inventory and Forecast: 1990-2020*, ANR, April, 33 pp. Appendix A. https://anr.vermont.gov/content/anr-climate-action-office-releases-annual-greenhouse-gas-emissions-inventory-vermont

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Note: these figures are preliminary and with partial data, but are included as examples of Chevron's and ExxonMobil's differential emissions from production and refining. In Fig A-7 we show Esso/SONJ/Exxon data since 1950, but lack Mobil refinery data prior to its merger with Exxon in 1999. The Chevron data is more complete from 1990 forward, and shows that refinery output product emissions are in some years lower than production-based emissions.

Figure A-6. Chevron's estimated emissions from petroleum production, refinery output, and product sales 1950-2022; excludes natural gas and coal.

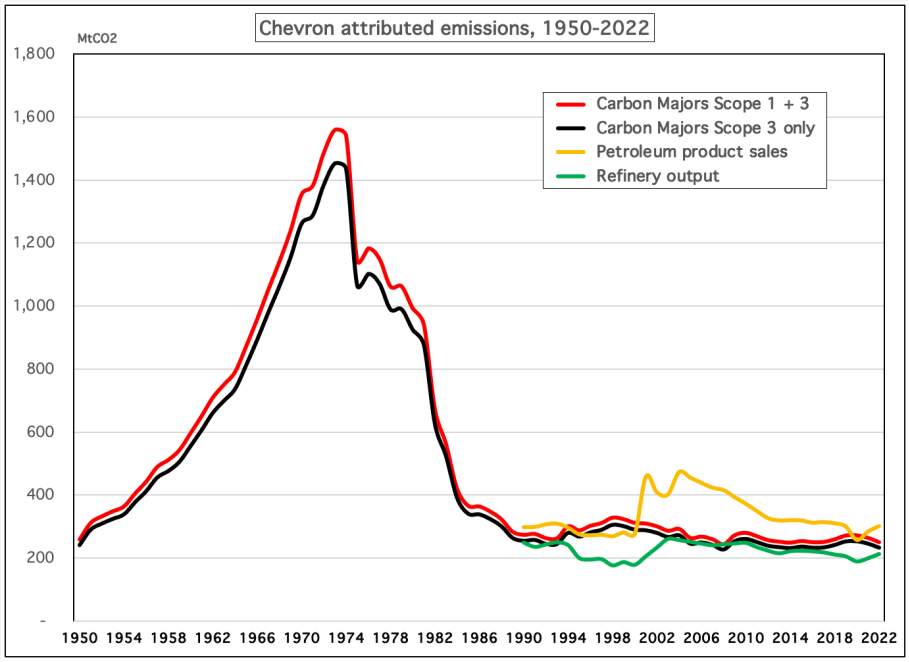

Figure A-7. ExxonMobil's estimated emissions from petroleum production, refinery output, and product sales 1950-2022; excludes natural gas and coal.