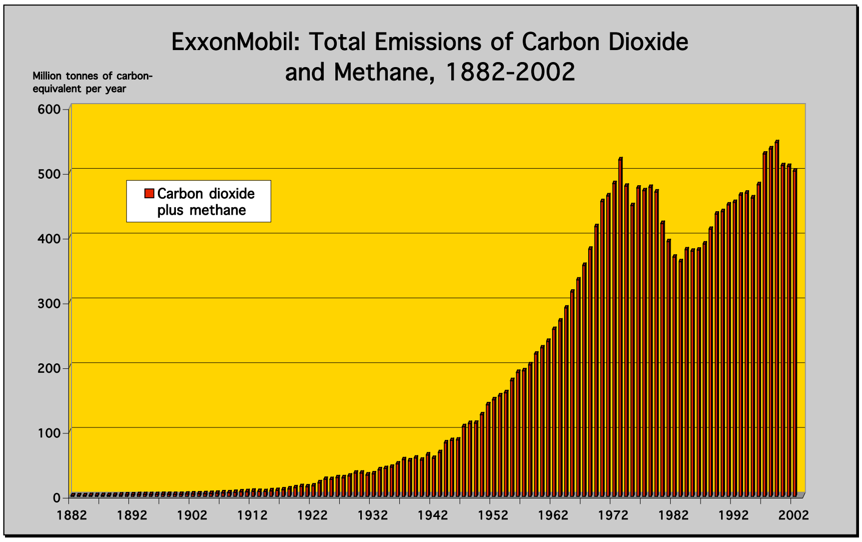
ExxonMobil Corporation Emissions Inventory 1882-2002

Methods & Results



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Lassoing an iceberg approaching the Hibernia platform off Newfoundland.
Photo courtesy ExxonMobil.com, *The Lamp*, Winter 2002-2003.

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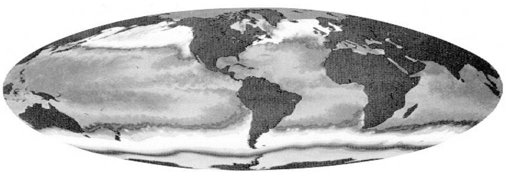

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Methods & Results

Introduction

Smart oil companies have publicly recognized the threat of climate change in recent years, committed to reduce emissions of greenhouse gases, and have made impressive progress — at a profit to shareholders.[1] The realization that being a large carbon emitter conveys an increasingly unacceptable business risk drives the leaders within the trillion-dollar petroleum industry to seek innovative solutions.[2] Indeed, the opportunity to reduce costs and risks while enhancing shareholder values will determine progressive companies' climate actions both within and beyond the energy sector. Many companies are profitably pursuing the innovative thinking, products, and services that effective climate policies provide, despite the U.S. government's disregard of the economic and national security benefits thereof. The present work is not, however, a guide to such opportunities. Instead, our job has been to conduct the first comprehensive account of emissions of climate-altering gases by the world's second largest oil company over its 120-year corporate history. That company is ExxonMobil Corporation.

The results are contained in the attached spreadsheet.[3] This paper focuses on the methods used to estimate emissions, including the assumptions, inferences, carbon coefficients, data sources, gases included, boundary description, and caveats. We relied on corporate data when available, and on careful reasoning and relevant proxy data when not. We assess and assign uncertainty ranges to the figures for each emissions source.

Lest there is any doubt: this study is only the first approximation of ExxonMobil's emissions over its history. Future revisions will hopefully benefit from better access to company data, which we were in no circumstances granted beyond the published corporate histories, annual reports, filings with the U.S. Securities and Exchange Commission, and limited web-posted data. Readers are encouraged to review the spreadsheet, its thirteen worksheets, numerous charts, and hundreds of comments to specific cells and column headers that detail the data sources, calculations, formulas, use of proxy data, extrapolations, and notes. We encourage readers to advise us of errors of fact or interpretation at the author's electronic address listed on the inside cover.

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[1] The smartest companies have achieved internal GHG reductions of up to 10 percent *below* 1990 emissions, have publicly stated that anthropogenic climate change is substantially caused by their industry and thus worthy of their mitigation, have financially committed to help create a lower-carbon energy system as well as to help customers reduce their emissions. In the process, they also have learned a great deal about the most effective and profitable ways to reduce emissions. See, for example, Swisher 2002, Watts 2003, and Cogan 2003.

[2] Worldwide oil and gas revenues total approximately $2 trillion per year. Economides & Oligney (2000, p. 100) suggest $2 trillion (oil only). ExxonMobil's revenues totaled $205 billion in 2002, second only to Royal Dutch/Shell Group with $236 billion (*Financial & Operational Information 1998-2002*, p. 5). ExxonMobil (2003) *2002 Annual Report*, p. 32.

[3] Heede, Richard (2003) *ExxonMobil Corporation: Emissions Inventory 1882-2002: Spreadsheets*, Climate Mitigation Services, Snowmass, Colorado, USA, for Friends of the Earth Trust Ltd, London, 13 sheets, 90 pp.

Purpose and scope of work

The objective of this phase of the project is to inventory annual and aggregate historic emissions of the two principal greenhouse gases (carbon dioxide and methane) by ExxonMobil Corporation since its early days as the Standard Oil Company; that is, from 1882 to 2002.[4] To accurately allocate to ExxonMobil its emissions over time we not only have to gather data for each previously independent company prior to their merger in 1999, but also equitably allocate a proportion of Standard Oil's pre-1912 emissions to these two of the 34 companies that made up Standard Oil at its court-ordered dissolution in 1911. This allocation is based on each disaffiliated company's net asset value as a percentage of Standard Oil Company's pre-dissolution value.

We detail estimated annual emissions of carbon dioxide and methane from the combustion of the products marketed or consumed internally by Standard Oil in 1882 forward to ExxonMobil in 2002. While we clearly distinguish between emissions from the combustion of products sold versus emissions from each company's own operations, *both categories are included*.[5] Each emission source is inventoried in a separate worksheet, with sources of original data clearly identified. The emissions from every source are summarized for 1882-2002 on the "GHG Sum" and "Special Sums" worksheets, and groups of emissions are also shown, such as total external and internal emissions, total carbon emissions, total marketed petroleum products, and sums of carbon and methane (in carbon-equivalents).

Boundary definition, corporate entity, and gases covered

Boundary: All emissions of carbon dioxide and methane released to the atmosphere from company-owned facilities and equipment *and* from their customers' combustion of products sold by the company are included. We carefully estimate the fraction of each type of fuel sold that is combusted into carbon dioxide, regardless of whether the combustion is done at company facilities, or on behalf of company interests, or in equipment utilized by its customers. The emissions from company-owned facilities are usually called "internal" or "direct" emissions. We also include emissions from power plants operated by utilities around the world from which ExxonMobil purchases electricity.[6] We estimate emissions from fuels used to transport the company's crude oil and petroleum products from production or gathering facilities to refineries and wholesalers and, ultimately, to service stations and final suppliers.

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[4] John D. Rockefeller and four partners organized The Standard Oil Company in Cleveland, Ohio in June 1870, to "manufacture petroleum and dealing in petroleum and its products." Rockefeller had entered the oil refining and shipping business in 1862, three years after the first well had struck "rock oil" in the Oil Regions of western Pennsylvania. We could have included oil sales and emissions starting in 1870, but a reliable data set is not available for these early years. The omission of the first dozen years decreases total estimated emissions by less than 0.1 percent. Standard Oil Company was reorganized in 1882 as the Standard Oil Trust (operating as Standard Oil Company as well as a myriad of other refining, transportation, and product interests), forced to "dissolve" in 1892, and reorganized as Standard Oil Company (New Jersey), known simply as "Jersey." In 1899, Jersey became the sole holding company for all of Standard's various interests. Its phenomenal control of the oil sector lead the Federal Government to file a suit in 1906 charging the company with running a monopoly under the Sherman Antitrust Act of 1890. Standard Oil Company (New Jersey) was ordered dissolved into 34 separate companies when the U.S. Supreme Court upheld a lower court ruling in 1911. This report focuses on two of these disaffiliated companies that are once again combined as the ExxonMobil Corporation.

[5] Emissions inventory protocols tend to focus on emissions from equipment or sources that are within the substantial control of the company or entity in question. Certainly, carbon dioxide vented from ExxonMobil production platforms, or natural gas flared at its refineries, or fuel used to generate electricity at its chemical plants are under greater control than electricity purchased from utilities. Broadly, our intention is to include all emissions that result from the company's pursuit of profit, whether "internal" or "external" to its own operations.

[6] ExxonMobil has increased its self-generated power at many of its plants and facilities (to ~2,900 MW in 2002). See the worksheet entitled "Company Energy Use" for additional information.

Corporate entity:[7] In order to account for the carbon dioxide and methane gases emitted to the atmosphere from the combustion of products marketed by ExxonMobil Corporation and its predecessors, and the emissions from company operations, we include 52 percent of the products marketed by Standard Oil Company from 1882 to 1911, and 100 percent of the products marketed by its descendants: Socony-Mobil 1912-1999, Standard Oil Company (New Jersey) 1912-1999, and ExxonMobil Corporation from 1999 to 2002.[8]

We include, to the extent that sources enable us to do so, the carbon-based commodities sold by each company and their hundreds of entities under varying degrees of ownership or control, the share of production and/or sales from joint ventures, and special production and marketing agreements.[9] Royalty production is netted out. Per our boundary definition's inclusion of products *marketed* (not merely extracted or processed), oil and gas produced by other companies are included when such commodities are purchased and *re-sold* by ExxonMobil or its affiliates. Sales to re-sellers, wholesalers, marketers, and governments are included. The intent is to account for all carbon sales and their combustion to CO_2. Data coverage and reliability varies — especially in the early decades of ExxonMobil's history.

Gases included: We include carbon dioxide from the complete combustion of fossil fuels (oil, gas, and coal), hydrocarbon fuels oxidized to CO_2, flared natural gas, and the direct venting of CO_2 removed from natural gas. We also include emissions of methane (CH_4), the principal sources of which are leakage from oil and gas production sites, shipping, storage, processing facilities, and fugitive emissions from coal mines. As a measure of the relative importance of these two gases, consider that methane plus carbon dioxide equal 93 percent of total U.S. greenhouse gas emissions. Of the emissions inventoried by Royal Dutch/Shell Group, 95 percent are from carbon dioxide and methane combined.[10]

[7] For simplicity's sake we use four primary corporate names: 1. Standard Oil Company refers to its pre-1912 corporate entity; 2. Standard Oil Company (New Jersey) is herein typically SONJ or SONJ-Exxon and refers to the post-1911 entity that became Exxon in 1972; 3. Standard Oil Company of New York is herein referred to as Socony or Socony-Mobil; and 4. ExxonMobil Corporation, herein referred to as ExxonMobil (but on occasion XOM, its ticker symbol), created by the merger of Exxon Corporation and Mobil Corporation in 1999. Both Exxon and Mobil absorbed, spun off, founded new affiliates, and even briefly invested in joint ventures over each company's long history (e.g., SONJ took a 50 percent stake in Humble Oil & Refining Company in 1917, and Socony merged with Vacuum Oil in 1931 [Socony-Vacuum Oil Company changed its name to Socony Mobil Oil Company in 1955, to Mobil Oil Corporation in 1966, and to Mobil Corporation in 1976]).

[8] We therefore include a total of 52 percent of Standard Oil Company's sales and emissions from 1882 through 1911 to ExxonMobil, of which we allocate 43 percent and 9 percent to SONJ and Socony, respectively. SONJ: Gibb & Knowlton (1956) *The Resurgent Years, 1911-1927*, p. 6: "aggregate net value of the thirty-three disaffiliated corporations totaled $375,000,000, or 57 per cent of Jersey's predissolution total net value"; hence SONJ equals the remainder (43 percent). Socony: Yergin (1991) *The Prize*, p. 110: "Next largest, with 9 percent of net value, was Standard Oil of New York." After 1911 we allocate the full amount of sales and emissions to each company. Note: Another source (Pederson, Jay (2000) *International Directory of Company Histories*, vol. 32, p. 178) suggests a higher allocation of net asset value, and hence of SONJ's proportion of total sales and emissions for 1882-1911: namely that SONJ acquired $285 million of the previous net asset value of about $600 million, or *47.5 percent*. The difference is not in the $285 million, but in the value of the parent company, or $600 million *vs* $658 million (calculated from the above Gibb & Knowlton data). The quantitative difference is a total of 7.7 million tonnes of carbon on 1882-1911 emissions of 89 MtC, or 0.038 percent of total 1882-2002. We apply the 43 percent allocation factor for SONJ based on Gibb & Knowlton in our study.

[9] Including subsidiaries, affiliates, joint ventures, investment properties, and production or marketing agreements. If not wholly owned, we count the sales based on each company's equity share. Our reliance on published data, ambiguities in the published records, and our lack of access to corporate records, leaves little doubt that we have not accounted for all such sales. Production and/or sales may not always reflect equity share, and it is probably the case that not all fossil fuel produced by the companies have been accounted for (such as all oil produced under production sharing agreements or under contractor-only contracts).

[10] Carbon dioxide of 100 million tonnes, 0.24 million tonnes of methane, and 0.015 million tonnes of "other Kyoto gases" equals 106 million tonnes carbon dioxide equivalent, of which CO_2 + methane = 100.88 million tonnes CO_2-equivalent, or 95 percent of total. Admittedly, Shell's boundaries differ from ours (e.g., Shell does not include emissions from consumption of electricity, or some other transportation fuels). Royal Dutch/Shell Group of Companies (2003) *The Shell Report*, Data Tables.

Both ExxonMobil's unpublished inventory and this study omit nitrous oxide (N_2O), HFCs, PFCs, and SF_6 emissions (though Royal Dutch/Shell Group and some other oil companies do inventory all of these gases as well as the non-Kyoto CFCs and halons). Our only reason for omitting these emissions — all part of the Kyoto Protocol basket of six gases and included in most inventory protocols — is that no relevant data is published by ExxonMobil upon which to base an estimate for recent years, much less for the past century. In the U.S., nitrous oxide emissions make up a small percentage of national GHG emissions (5.2%, 2001) and the major sources are from vehicles. ExxonMobil's principal N_2O emissions are from the manufacture of adipic acid — one of two main ingredients for nylon polymers — and no manufacturing data is available from the company for an emissions estimate.

Table 1
Boundary table for ExxonMobil GHG Emissions

Gas	Scope 1 XOM direct	Scope 2 XOM indirect	Scope 3 XOM external	Not covered / beyond boundary
Carbon dioxide	**Building & facility fuel. Steam plant fuel. Other heating & water heating fuels.**	**Emissions at electric utility power plants** (consumption)	**Carbon dioxide from combustion of marketed fuels.**	**Employees' commuting fuels. Employee, management, & board air travel on company business, corporate aircraft.**
	Fuel for on-site electric generation.	**Purchased steam.**	**Oxidation to CO_2 of lubricants, solvents, & other volatiles.**	**Fuels used to transport equipment, materials:** no supply chain transport, except XOM products or in XOM trucks, ships.
	Flared natural gas: production platforms, tank farms, pipelines, refineries, & facilities.		**Emissions from fuels & electricity at XOM franchises** (service stations, fuel dealers).	**Carbon sequestered:** in lubricants, petrochemicals, asphalts, etc; vegetation on XOM lands, CO_2 sequestered by phytoplankton on offshore leases.
	Bunker in coast-wise & blue-ocean tankers (XOM owned).		**Bunker in coast-wise & blue-ocean tankers** (leased).	**Upstream emissions:** water supply utilities, manufacturing of cement and paper.
	Diesel fuel used by company product delivery tanker fleet.			**Fuels used by contractors** (helicopter service companies, tug-boats, trucking companies).
	CO_2 vented from gas production platforms & processing plants.			**Downstream emissions:** waste water treatment plants, municipal & industrial waste facilities.
	Other company transportation (if company vehicles or fuels are used).			**Supply manufacturing:** steel and other materials for platforms, pipelines, drill rigs, oil storage tanks, chemical works, crude oil tankers, barges, trucks, etc.
	Pipeline fuel.			**CO_2 sold to beverage industry, other industrial** (Mobil: 13,000 tonnes of carbon/yr 1980s).
	Refining and processing fuel.			**Purchased fuel at coal mines, shipping terminals; FedEx; miscellaneous shipping & ops.**

Methane	**Fugitive methane:** production platforms, pipelines, compressor stations, processing plants, gas storage facilities, LNG tankers, seals, and valves.	**None included.**	**None included.**	**Methane from industrial and municipal landfills; wastewater treatment plants; wetlands owned or leased by Exxon-Mobil; methane from non-XOM coal mines supplying coal to utility power plants.**
	Fugitive methane: XOM-owned (or equity) coal mines, terminals.			**Methane leakage from gas-consuming end-use equipment, boilers, pipes, and appliances.**
Nitrous oxide	**None included**	**None included.**	**None included.**	**N_2O emissions from adipic acid manufacture are not estimated** (no data available from XOM)
				N_2O emissions from nitrogen fertilizers applied to company lands. Emissions from XOM-manufactured fertilizers, if any.
				Nitrous oxide emissions from coal-fired power plants.
				N_2O emissions from consumers' use of XOM-marketed fuels.
HFCs, PFCs, SF_6, CFCs, HCFCs	**None included.**	**None included.**	**None included.**	**Coolant leakage from company vehicles' ACs. Commercial building chillers, central AC systems, refrigerators, etc.**
				Also not included: leakage and non-recovery from industrial chillers. Other refrigerants.

This boundary table summarizes the emissions included and does not fully elucidate the many nuances of what is counted, how, when, sources of data, proxies employed, and inferences, assumptions, and interpolations made. Readers are referred to the methodological discussions embedded in the spreadsheet's cell comments to discern how the "rubber meets the road" in the application of this boundary definition. The "not included/beyond boundary" column attempts to outline emissions sources that a more comprehensive estimate may wish to include (were the data and time available), as well as items we consider important to include but could not due to paucity of data. XOM = ExxonMobil Corporation.

The boundary table graphically elaborates on the "boundary" within which we count all gases and emissions as attributable to ExxonMobil.[11] Scope 1, 2, & 3 are included in our emissions inventory, whereas the last column describes emission sources that are *not* included and/or beyond the boundary.[12] While many companies follow "standard protocols," inventories nonetheless differ substantially in terms of gases included and company-specific boundaries. The result is that no two inventories are strictly comparable — just as our inventory differs from the definition and methods followed by Royal Dutch/Shell and other oil company

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[11] We are extending the sphere of responsibility to include corporate stewardship of its products manufactured and sold from the conventional border at the company fence to a life-cycle or "cradle to grave" responsibility. A number of progressive companies (e.g., Electrolux, STMicroelectronics) are incorporating product life cycles within their boundary. As Bill McDonough and others have pointed out, a sustainability-oriented company would express its responsibility as "cradle to cradle" — except that in ExxonMobil's case its products are degraded through their combustion into heat and CO_2, and their products consequently cannot be remanufactured into a next-generation product (except for recyclable lubricants, plastics, and polymers).

[12] For a functional description of scope 1, 2, and 3, see World Resources Institute & World Business Council for Sustainable Development (2001) *The Greenhouse Gas Protocol: a corporate accounting and reporting standard*, Washington, DC, and Geneva. www.ghgprotocol.org, www.wri.org, & www.wbcsd.org

climate reports. We have made an effort to be clear about our boundary, gases, methods, and results, however, in order to facilitate comparison to other emissions reports in the future.

Credits and offsets: In the course of its competitive and cost-sensitive business, ExxonMobil has undertaken numerous profitable emissions-reducing measures, without which its internal emissions would be considerably higher. Any future accounting of current or projected emissions will take such measures into account (if for no other reason than as potential marketable carbon reduction credits), *although we have not done so here*, since our objective is to estimate historic emissions, not hypothetical or future emissions.

Another creditable factor is ExxonMobil's planting of "more than 2 million trees since 1996" through a partnership with American Forests; we estimate this credit to be small relative to ExxonMobil's emissions — ~0.01 million tonnes of carbon (MtC) offset per year. While a *billion* or more trees would have to be planted every year to offset just a *tenth* of annual internal emissions (of ~100 MtC-equiv.), ExxonMobil can readily reduce internal emissions by a tenth through deployment of cost-effective technologies and smarter practices. Large opportunities to reduce emissions from internal sources, including reducing electricity purchased from electric utilities, remain available to the company and are, we hope, being seriously evaluated by ExxonMobil and its consultants. Indeed, the company has already reduced emissions, although it has not detailed such efforts.[13] Greater transparency about its current emissions, venting & flaring practices, and energy intensities may have allowed us to assess such opportunities with some useful specificity. Experience at other companies suggests that ExxonMobil can achieve climate-mitigation savings with a better return on capital invested than the 13.5 percent the company and its shareholders realized in 2002.[14] It is certain that ExxonMobil can dramatically improve its performance in this regard until its emissions have been reduced to *half or less* of what they are today.[15] The more risk-averse oil companies are also working to reduce the average carbon intensity of the energy they market.

Principal sources

The data used are, in most cases, drawn from company production and marketing reports, and thus considered accurate. We made extensive use of data tables and appendixes published in the three of the four *Histories of Standard Oil Company* listed below, as well as "Defendant's Exhibits" of the Supreme Court case records. We also used Standard Oil Company (NJ) annual reports back to 1930, Socony-Mobil back to 1950, and Form 10-Ks (similar to annual reports and filed annually with the U.S. Securities and Exchange Commission) back to 1978. Sales of natural gas and coal production were unevenly reported in all sources, even in recent decades, and scant mention of natural gas is made in any of the histories of Standard Oil.

Estimating emissions of carbon dioxide from the combustion of the marketed fossil fuels is straightforward (once the fraction of marketed fuels that is combusted rather than sequestered is determined). Greater degrees of uncertainty arise with estimates of vented and flared gas,

[13] Frankly, it's impossible to discern what's going on with ExxonMobil's emissions, given the scant data. Data appear to show slight absolute increases 2000-2002 that only become decreases when normalized to emissions *rates* per unit of throughput. Emissions from gas flaring declined due to decreased Nigerian production, and not, apparently, from improved performance. ExxonMobil Corp (2003) *Corporate Citizenship Report*.

[14] ExxonMobil (2003) *2002 Summary Annual Report: Staying the Course, Yesterday, Today & Tomorrow*, p. 29.

[15] It is beyond the scope of this report to characterize the company's opportunities to profitably reduce emissions of greenhouse gases. Nor can we detail here the potential liabilities, financial or otherwise, of the company's high profile of climate obstructionism, whether from the perspective of its fiduciary responsibility to reduce undue financial risks, enhance rather than erode shareholder values, foresee regulatory surprises, or avoid corrosion of the company's public image and customer loyalty.

methane leakage, and company energy use — for which no company data are available — in which cases we use well-documented proxy data supported by research into each of these emissions sources. We recognize that future research will reveal better methods, improved proxy data, or better access to company records. Oil companies are quite guarded about such data, and we used a varied set of proxies, outside data sources, and independent estimation methods. All data sources are listed in the attached bibliography, and all of our methods and calculations are described in comments to cells in each worksheet.

A list of principal sources:

Hidy, Ralph, & Muriel Hidy (1956) *Pioneering in Big Business: History of Standard Oil Company, 1882-1911*, Harper and Brothers, NY, 1st edition, 839 pp.

Gibb, George Sweet, & Evelyn Knowlton (1956) *History of Standard Oil Company (NJ), 1911-1927: The Resurgent Years*, Harper and Brothers, NY, 743 pp.

Larson, Henrietta, Evelyn Knowlton, & Charles Popple (1971) *New Horizons: History of Standard Oil Company, 1927-1950,* Harper & Row, NY, 820+ pp.

Wall, Bennett, Gerald Carpenter, & Gene Yeager (1988) *Growth in a Changing Environment: A History of Standard Oil Company (NJ) 1950-1972 and Exxon Corporation 1972-1975*, McGraw Hill, 1020 pp. (Not a useful source of marketing data.)

Standard Oil Company (New Jersey) / Exxon Corporation (1930-1999) *Annual Reports*, New York, NY, and Irving, TX.

Exxon Corporation (1986-2002) *Form 10-K to the Securities and Exchange Commission*, Washington, DC, www.sec.gov/edgar/; also see Disclosure, Inc. for copies of Form 10-Ks and Annual Reports, www.disclosure.com, 800-638-8241.

ExxonMobil Corporation (2000-2003) *Annual Reports*, Irving, TX, www.exxonmobil.com (also see www.exxon.com and www.mobil.com)

SOCONY-Vacuum-Mobil Corporation (Standard Oil Company of New York) (1949-1999) *Annual Reports*, New York, NY; also Form 10-Ks filed with the Securities and Exchange Commission, Washington, DC, www.sec.gov/edgar/

Supreme Court of the United States (1910) *United States* v. *Standard Oil of New Jersey*, Defendant's Exhibits 266 and 267, vol. 19, page 626.

We used numerous other sources for comparison purposes (e.g., Shell inventories of GHG emissions, and oil and natural gas production and sales), as sources of proxy data, domestic greenhouse gas emissions, carbon factors, national venting and flaring rates, energy inputs to refineries, and so forth. See the Excel spreadsheet and its detailed comments to data series and calculation methods, and the attached bibliography for a full source listing.

Results

Over the 120-year history of ExxonMobil we inventoried 20.3 billion tonnes of carbon emitted as carbon dioxide, plus 199 million tonnes of methane released to the atmosphere. If we convert methane emissions to carbon-equivalent we get total emissions of 21.5 billion tonnes of carbon-equivalent. Of this total, we estimate that 82.3 percent is from customers' combustion of marketed products (oil, gas, and coal), collectively termed "external" emissions, and the remainder of 17.7 percent is a total of venting and flaring, company energy use, and fugitive methane from company operations (collectively called "internal" emissions in the table below).[16] See the attached Excel spreadsheet for details on emissions by year — and by fuel sold and by company activity.

[16] Cogan: "XOM says 13% of CO_2 from its petroleum products come from production. Customer use accounts for the other 87%." This appears to differ considerably from our results, but we're comparing apples to oranges. Our estimate includes coal and natural gas, not just petroleum; both estimates presumably include venting and flaring; XOM may not include fugitive methane, whereas our estimate does (in units of carbon-equivalent). Cogan, Douglas (2003), p. 92. In our result, if we look at emissions of carbon dioxide only, company emissions are 12.6 percent to customers' emissions of 87.4 percent. See discussion of "Company energy use" below.

The carbon and climate impact modeling performed by Jim Salinger and Greg Bodeker of New Zealand's National Institute of Water and Atmospheric Research for this project takes into account the *year* of emissions — not merely the total for 1882-2002 as summarized here — so as to estimate ExxonMobil's share of emissions relative to other anthropogenic sources of atmospheric carbon dioxide, methane, and nitrous oxide. Readers are referred to the NIWA report for the significance of ExxonMobil's and its predecessors' annual emissions in the overall carbon cycle and other anthropogenic sources, attribution of the equivalent atmospheric carbon concentration, temperature increase, and sea level rise.[17,18]

Table 2.
ExxonMobil's GHG emissions 1882-2002

Emission source	Emissions million tonnes carbon	Percent of total carbon dioxide
Kerosene, jet fuel	**786**	**3.9**
Gasoline, naphthas	**4,146**	**20.4**
Diesel, heating oils	**4,114**	**20.3**
Heavy fuels	**3,349**	**16.5**
Specialty products	**1,074**	**5.3**
Aggregate oil	**1,323**	**6.5**
Total oil	**14,792**	**72.9**
Natural gas	**2,545**	**12.5**
Venting & flaring	**597**	**2.9**
Coal	**394**	**1.9**
Company energy use	**1,954**	**9.6**
Total carbon	**20,281**	**100.0**
Methane (CH_4)	**199**	
Methane (Carbon-equiv)	**1,251**	***Percent of everything:***
Total external (C-eq)	**17,730**	**82.3**
Total internal (C-eq)	**3,802**	**17.7**
Total everything (C-eq)	**21,532**	**100.0**

[17] 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, for Friends of the Earth Trust Limited, Project FOE03103, www.niwa.co.nz, December, 49 pp.

[18] A minor correction was made to our estimate of kerosene marketed by Mobil in 1995 and coal mined in 1992 (and thus fugitive methane from coal mined in 1992). Numerically, this change is very slight — 21 million tonnes of carbon-equivalent lower, or less than 0.1 percent of the 21,532 million tonne total — but we wish to highlight the reason for slight differences between Table 2 and data in the NIWA report.

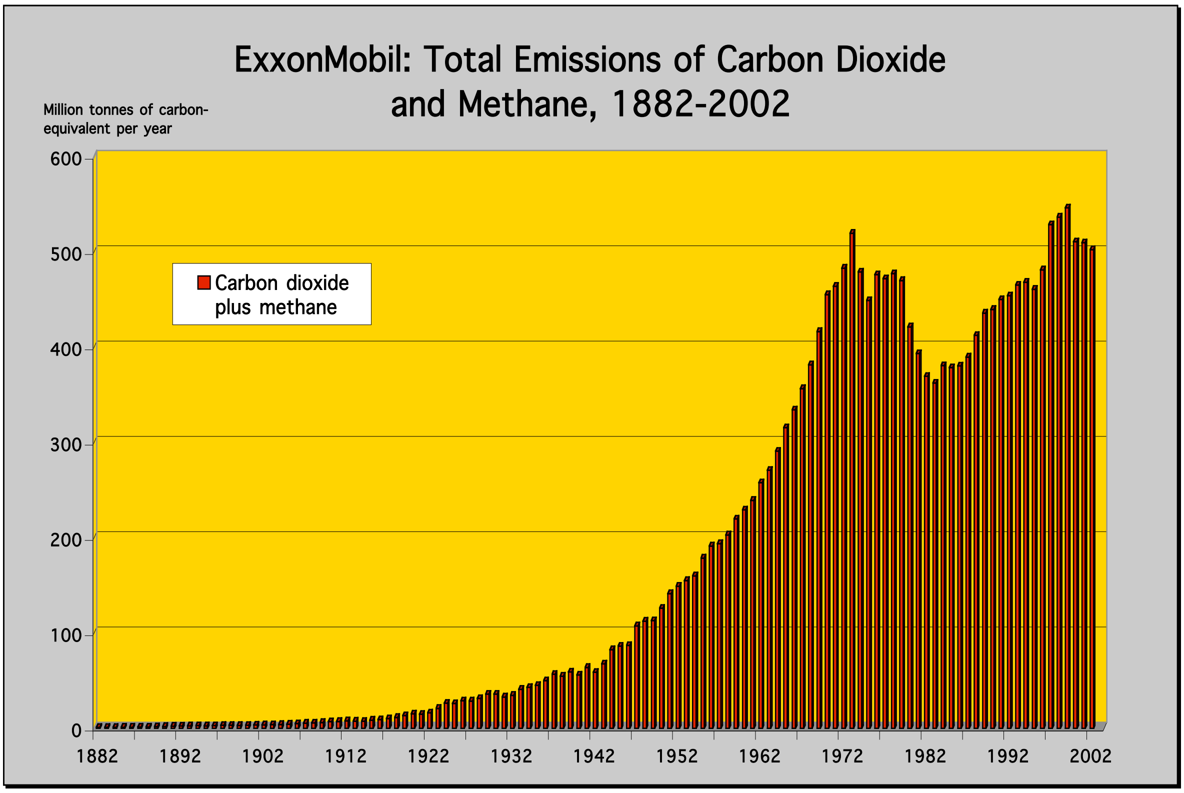

Fig. 1. Total emissions of carbon dioxide and methane by ExxonMobil Corporation (and its predecessors) from 1882 to 2002. It inventories emissions from the combustion of marketed products and from the corporation's equipment and facilities, including energy consumed. ExxonMobil reached the first 25 percent of emissions, as a fraction of total emissions 1882-2002, in 1967, 50 percent in 1978, and 75 percent in 1992.

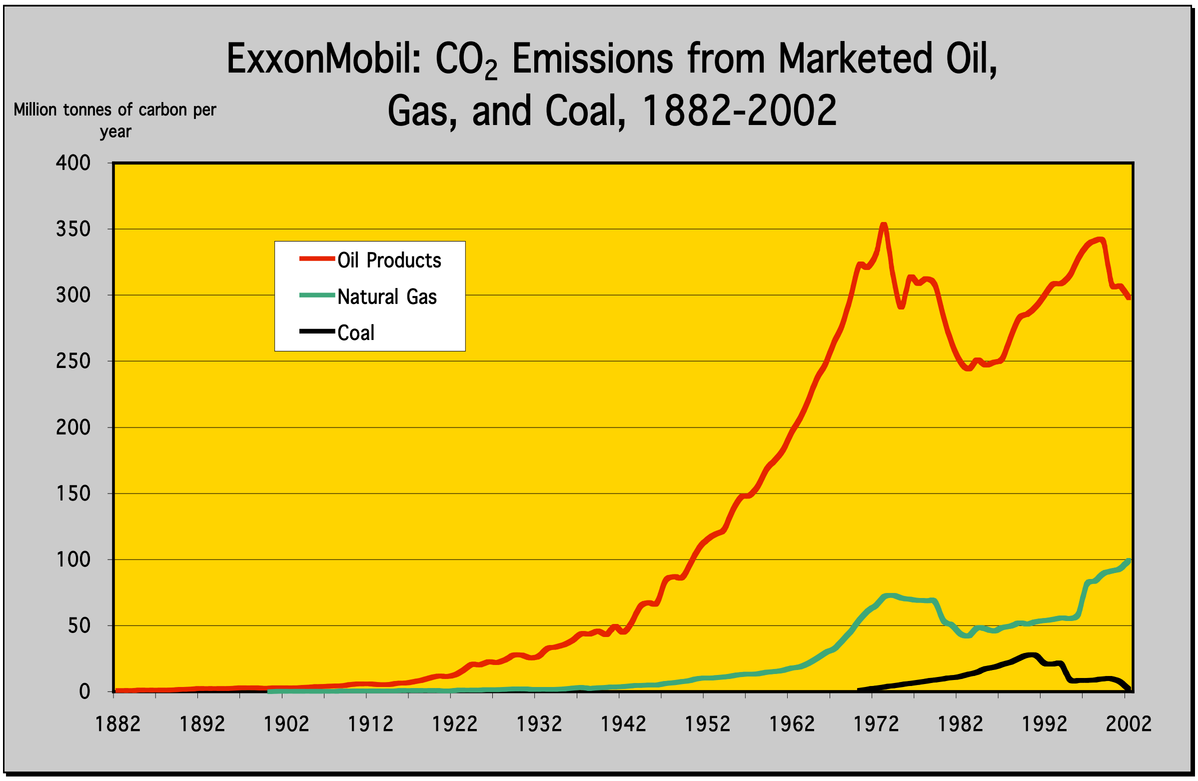

Figure 2. Annual carbon emissions by type of marketed fuel. Heede (2003) *ExxonMobil Corporation: Emissions Inventory 1882-2002*. Charted quantities are not stacked.

Methods, sources, & caveats

Kerosene & jet fuel

Uses & carbon coefficients

Kerosene fuels are used in residential appliances (heaters, lanterns, and stoves), in developing countries for lighting and cooking, and, in a slightly different formulation, as fuel for jet turbine and turboprop aircraft engines. We report kerosene as a separate category from the other middle distillates, both because of a slight variance in carbon content and to follow the data available in most SONJ and Socony-Mobil annual reports. Some reports do combine non-aviation kerosene with middle distillates, but the bulk of kerosene sales are reported as a line item. The carbon emission rate of kerosene is 19.72 kg of carbon per million Btu (kerosene-based jet fuel is slightly lower). The fraction of carbon in kerosene that is fully combusted to carbon dioxide is estimated to equal 99.0 percent.[19]

Data, sources, and caveats

Reliable kerosene sales data cover 1927-2002; we report kerosene sales for 1882-1926 under aggregated products. The primary data sources for kerosene sales by Standard Oil Company (New Jersey) are Larson *et al* for 1927-1950, and company annual reports and SEC Form 10-Ks for 1960-2002 (SONJ annual reports do not show kerosene sales prior to 1960). Socony-Mobil does not break out kerosene sales until 1991, instead reporting kerosene with middle distillates.[20] (Note: Socony-Mobil does not specify sales for any product until 1968; prior to 1968 all Socony-Mobil product sales are reported in this study under aggregated products.) Finally, ExxonMobil reports "total market and supply sales" for 1996-2002 (thus combining Mobil and Exxon sales prior to their merger in 1999).[21] However, most prior annual reports and SEC Form 10-Ks only report "global product sales volume," the difference *possibly* being that earlier reports do not include products sold to other large resellers and oil companies.

We do show product sales of kerosene, gasoline, and diesel-type fuels for 1890 and 1897 on the respective worksheets for illustrative purposes, which are not added to total sales or emissions (using data from Hidy & Hidy).

Range of uncertainty (percent, quantity)

There is very little uncertainty associated with the source data (assuming there were no quantitative errors in the *Histories* or annual reports, and the data were transcribed correctly into the worksheets). The combustion factor is also well known. While there may be a delay

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[19] Equals 26.033 lbs CO_2 per U.S. gallon and 173.906 lbs CO_2 per million BTU. Fraction of fuel combusted from Energy Information Administration (2001) *Emissions of Greenhouse Gases in the United States 2000*, p. 106. The carbon coefficients of all products and commodities are summarized in Table 4.

[20] Reporting standards are not explicit in corporate annual reports, especially with respect to physical quantities. Inquiries for explication to several petroleum experts and trade associations, including ExxonMobil staffers, shed little light on the reporting ambiguities. Operating summaries typically do not define type of product, and the reported quantities often shift (i.e., reporting kerosene as a separate line item one year and not the next [without explaining the change], and including sales of residential kerosene with jet-fuel). Not to mention the changing complexities of production vs refinery runs *vs* marketing — in the case of natural gas — "made available for sale" *vs* "gross sales" *vs* "net sales" *vs* "marketed production"). Also, international sales are occasionally reported in a different manner than domestic sales.

[21] "Market sales are to retail sale dealers, consumers (including government and military), jobbers, and small resellers. Supply sales are to large oil marketers, large unbranded resellers, and other oil companies." ExxonMobil (2003) *Annual Report, 2002*, p. 75. It is not clear whether prior reports' showing "global product sales" meets the same definition, specifically, that they include sales to other oil companies and resellers.

between the purchase and combustion of kerosene, as with all fuels (especially utility coal), this will not materially affect estimated emissions. Finally, we do not claim to have accurately estimated total sales of kerosene by all of the companies in question. Rather, we have sought to assemble a reasonable estimate of kerosene sales within the more important context of estimating — with greater accuracy — the amount of total oil products sold and consumed. This is due to the fact that many of the reporting ambiguities disappear upon aggregating all petroleum sales. Thus the total amount of liquid fuels marketed has a greater degree of accuracy than do the individual product types.[22] Given the reliability of the basic data, we estimate that the calculated carbon emissions from the sale and combustion of kerosene to have an uncertainty of ±2.0 percent. This suggests a quantitative uncertainty of ±15.7 million tonnes of carbon on estimated 1927-2002 emissions of 786 million tonnes of carbon (MtC).

Gasoline & naphthas

Uses & carbon coefficients

Gasolines and naphthas are light and highly volatile fuels used in spark-ignition internal combustion engines, and in blended gasolines and gasohols. Naphtha-type jet-fuel is used primarily in military turbojet and turboprop aircraft engines due to its lower freezing point and suitability for high altitude operations. The carbon emission rate of gasoline is 19.38 kg of carbon per million Btu (naphtha is slightly higher). The fraction of carbon in gasoline that is combusted to CO_2 is 99.0 percent.[23]

Data, sources, and caveats

Gasoline and naphtha sales — "worldwide petroleum product sales of gasoline and naphthas" — are reported for SONJ and ExxonMobil from 1927-2002 (Larson, Knowlton, & Popple 1971, SONJ annual reports and SEC Form 10-Ks). Socony-Mobil's reported gasoline sales commence in 1968. Some sales of aviation gasoline (for general aviation piston aircraft) are included with gasolines and naphthas.

Range of uncertainty (percent, quantity)

Gasoline sales and emissions have the same uncertainties as discussed for kerosene. We assign an uncertainty range of ±2.0 percent, which translates to a quantitative uncertainty of ±82.9 million tonnes of carbon on total 1927-2002 gasoline-related emissions of 4,146 MtC.

Diesel, home heating oil, & related fuels

Uses & carbon coefficients

Diesel fuels and related middle distillates (home heating oils, kerosene, fuel oils #1-#4) are used in automobile and lorry diesel engines, and in non-road engines used in locomotives and agricultural machinery. While kerosene is classified as a middle distillate, we report this fuel type in a separate category to follow the reporting practice of most company reports. The carbon emission rate of diesel and related fuels is 19.95 kg of carbon per million Btu. The fraction of carbon in middle distillates that is fully combusted to CO_2 is 99.0 percent.

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[22] This discussion on uncertainty, reliability of data sources, and the adequacy of data coverage applies to all oil products, but which we will not repeat for each product type.

[23] Equals 26.033 lbs CO_2 per U.S. gallon = 173.906 lbs CO_2 per million BTU. Fuel combustion factor from Energy Information Administration (2001) *Emissions of Greenhouse Gases in the United States 2000*, p. 106.

Data, sources, and caveats

Sales of middle distillate fuels are reported for SONJ from 1927-2002 (Larson *et al*, SONJ annual reports and SEC Form 10-Ks). Socony-Mobil distillate sales reports start in 1968.

Range of uncertainty (percent, quantity)

Diesel and related sales and emissions have the same uncertainties as discussed for kerosene. We assign an uncertainty range of ±2.0 percent. This equates to a quantitative uncertainty of ±82.3 million tonnes of carbon on estimated 1927-2002 emissions of 4,114 MtC.

Heavy oils & residuals

Uses & carbon coefficients

Heavy fuels (or residual fuels, fuel oils #5 and 6, Navy Special, and Bunker C) are used in steam-powered ships, power plants, and for various industrial purposes. The carbon emission rate of heavy oils and residuals is 21.49 kg of carbon per million Btu. The fraction of carbon in residual fuels that is fully combusted to CO_2 is 99.0 percent.

Data, sources, and caveats

Sales of heavy fuels are reported for SONJ and ExxonMobil from 1927-2002 (Larson *et al*, SONJ annual reports and Form 10-Ks). Socony-Mobil product sales reports start in 1968.

Range of uncertainty (percent, quantity)

Heavy oil sales and emissions have the same uncertainties as discussed for kerosene. We assign an uncertainty range of ±2.0 percent. This means a quantitative uncertainty of ±67.0 million tonnes of carbon on estimated 1927-2002 emissions of 3,349 MtC.

Specialty products

Uses & carbon coefficients

"Specialty products" include: lubricants and lube stocks; waxes (candles, polishes); greases; solvents and naphthas for paint thinner, cleaning solvents, and inks; asphalts and road oils; pitch; and miscellaneous products, which include aromatic extracts, tars, absorption oils, synthetic gas feedstocks, specialty oils, and petroleum-based rocket fuels.

Varying amounts of these products are directly combusted — such as waxes, rocket fuel, and about half of engine lubricating oil. Other specialty products oxidize into the atmosphere — such as paint thinner, volatiles, and lubricating oil spilled onto driveways and waterways by do-it-yourself mechanics.[24] We estimate that 65 percent of specialty products sold are either directly combusted or oxidized over a relatively short time horizon.[25] Future research may result in a changed combustion/oxidation factor for product sales by both of these companies, or, better yet, a dynamic factor that evolves over time as the product mix and uses change.

[24] Consumers "intentionally" spill large quantities of engine oil. According to the American Petroleum Institute, an estimated 166-188 million gallons annually in the U.S. Personal communication, Aug96.

[25] The U.S. Energy Information Administration, taking the lead from the IPCC, suggests sequestration fractions of 0 to 100 percent for these individual products. Lacking a detailed breakdown of the composition of specialty products, and noting that petrochemical feedstocks are typically NOT included in specialty products, we use an estimated sequestration rate of 35 percent (meaning an oxidation and/or combustion factor of 0.65). This factor will be adjusted if warranted by further research. Taking year 2000 of ExxonMobil's reported sales of specialty products as an example, 0.65 of 1,282 kbbl/d = 833 kbbl/d = 9.4 percent of total product sales (8,887 kbbl/d). EIA (2003) *Emissions of Greenhouse Gases in the United States 2001*, US DOE, Appendix A6, pp. 104-107.

The carbon emission rates of specialty oil products vary tremendously, since the product category includes both light and heavy oils. We use the middle distillate carbon emission coefficient of 19.95 kg of carbon per million Btu. The fraction of carbon in specialty products that is combusted or oxidized to CO_2 is tentatively estimated to equal 65 percent.

Data, sources, and caveats

Sales of specialty products are reported for SONJ-Exxon from 1951-2002 (Larson *et al*, SONJ annual reports, and SEC Form 10-Ks). Socony-Mobil product sales reports start in 1968. For SONJ's estimated specialty product sales for 1927-1950, we deduct "Total Major Products" from "Total Products (excluding chemical products)"; this remainder approximates or is identical to the category of specialty products used in subsequent years. [26]

Range of uncertainty (percent, quantity)

While the basic sales data appears to have a high degree of accuracy, it has not been possible for us to research the uses and disposition of several dozen products over a 120-year history of ExxonMobil and its forebears. Nor do the published company reports shed light onto the specific product mix of "specialty products." We trust that future research — or collaboration with the company — will document and likely change our 65 percent combustion/oxidation factor, and perhaps reveal a dynamic combustion and/or oxidation rate over time. Given these unknowns, we assign an uncertainty range of ±6.0 percent. This equates to a quantitative uncertainty of ±64.4 million tonnes of carbon on estimated 1927-2002 emissions of 1,074 MtC.

Aggregated products

Uses & carbon coefficients

Aggregated products presents total oil sales and emissions for years in which we do not have data for individual product sales, which are Standard Oil Company for 1882-1911, SONJ for 1912-1926, and Socony-Mobil for 1912-1946. To account for the fraction of specialty products within aggregated products that are sequestered into lubricants, road oils, greases, and so forth rather than combusted, we apply a combustion factor of 96 percent of aggregated products. We use the carbon emission rate of crude oil of 20.25 kg of carbon per million Btu.

Data, sources, and caveats

Aggregated product estimated sales and emissions are based on Standard Oil Company's refinery deliveries from 1882-1911 (43 percent to SONJ and 9 percent to Socony), SONJ data for 1912-1926, and proportional allocation of Socony-Mobil 1912-1946.[27] (We do have product sales or refinery delivery data for selected years, e.g., 1890, 1897, 1912, and 1919;

[26] Larsen *et al*, 1971, table on "Worldwide Sales of Products, 1927-1950, Standard Oil Company (NJ)," p. 820.

[27] We develop two data sets regarding presumed Socony aggregated oil product sales for 1912-1946 (post-1946 we have data for world finished product sales from Socony's annual reports). The calculated fraction starts in 1912 with the known allocation of 9 percent of total Standard Oil Company net asset value (and thus presumed product sales) spun off to Socony. Standard Oil Company (New Jersey) inherited 43 percent of Standard Oil's net asset value, and thus 9 percent divided by 43 percent equals a ratio of 0.209. This becomes the allocation factor for Socony's aggregate product sales in 1912: that is, 0.209 of SONJ aggregate product sales = Socony product sales. Anchoring the other end of known data is the actual data for Socony starting in 1947. The 1945-1948 four-year average Socony/SONJ factor is 0.351, whereas the four-year average for our control column (which is actual SONJ data) divided by calculated Socony sales, has a 1945-1948 average factor of 0.348. This congruency test suggests that our calculated factor is reasonable. SONJ data for 1912-1927 ("total domestic and foreign deliveries") are from Gibb & Knowlton, 1956, p. 681. See the Aggregated Products worksheet for details. We also note that refinery deliveries include amounts of oil used for internal operations. Consequently, we do not estimate oil used under "Company energy use" for these same years.

we opt to use aggregated data rather than build up sales by product type based on four years' allocation factors; furthermore, some data are percentage distributions rather than physical quantities.) Inconsistencies are unavoidable, such as the differences between data sets. For example: SONJ data for 1911-1926 are for refinery *deliveries*, not total marketed sales, although the difference is probably minor in the early decades. Perhaps the greater source of uncertainty is the assumption that the inheritance of a certain fraction of Standard Oil Company's net asset value is equivalent to its inheritance of the same fraction of product sales. This affects our estimates of both successor companies' proportion of Standard Oil Company sales and emissions for 1882-1911. Still, this presumed factor meshes quite well with actual SONJ data at the 1911/1912 transition, with a variance of 0.83 percent.

Range of uncertainty (percent, quantity)

Estimated emissions for 1882-1911 total 0.44 percent of estimated emissions for 1882-2002, and while our estimate is based on refinery deliveries rather than total marketed fuels, even a large under-reporting error for these early years is insignificant to the overall estimate. Also, there is uncertainty about the fraction of non-combusted (non-energy uses of) product sales, as discussed in the section on "Specialty Products." We assign an uncertainty of ±4.0 percent, and thus a quantitative uncertainty of ±52.9 million tonnes of carbon on aggregate products estimated emissions 1927-2002 of 1,323 MtC.

Natural Gas

Uses & carbon coefficients

Standard Oil Company started marketing natural gas in a few Ohio and Pennsylvania cities in 1883, and owned or controlled nine gas companies by 1886. Standard's primary interest was in pipeline transport of natural gas, and secondarily its marketing, but management was eager to find markets for the gas being wasted in the field and received Rockefeller's blessing.[28] Natural gas was initially used as a lighting fuel, gradually found industrial markets, and now has myriad uses: space and water heating in buildings, process heating and shaft power in industry, small but growing uses as vehicle fuel (and possibly as a feedstock for future hydrogen vehicles), and as a nitrogen fertilizer and chemical feedstock. We have excluded chemical feedstock and other non-combusted natural gas uses based on U.S. non-fuel uses in 1999 of 3.35 percent. The amount combusted is a product of fuel uses (100 percent minus the non-fuel uses of 3.35 percent in 1999) times the fraction of natural gas combusted into carbon dioxide (99.5 percent): 0.9665 x 0.995 = 0.962. The carbon factor emission coefficient is 14.48 kg of carbon per million Btu.

Data, sources, and caveats

Gas marketing data are from company annual reports and SEC Form 10-Ks. These reports are not always consistent with respect to what is reported, ranging from "natural gas made available for sale" (net production from company production facilities, net of royalties, losses, shrinkage, and company consumption) to "gross production" to "net production" and "total amounts marketed" (including gas purchased from other producers and re-sold). The notes to cells and datasets on the Natural Gas worksheet specify the reported statistics and the sources used. Adding to the complexity is the fact that there are decade-long gaps in the published

[28] JDR's tune had evolved from caution ("We should keep this gas question in mind. We may make a mistake in going too fast.") in 1883 to enthusiasm in 1885 ("I am desirous to keep our National Transit Company pursue the gas business earnestly."). Hidy & Hidy (1956), p. 173.

data and sparse to no coverage in company annual reports and corporate *Histories*. We use other factors to make up for these data-gaps. For SONJ, for example, we take the company's fraction of total U.S. marketed gas (which we know equaled 4.8 percent in the 1930s) to backcast its sales using the same fraction back to 1912 (and back to 1900, but only for the 43 percent of Standard Oil that became SONJ in 1912). SONJ does not report gas sales from 1940 to 1962, and here we allocate 7.0 percent of U.S. gas sales (based on its rising share in the 1930s). This approach very likely underestimates actual SONJ natural gas sales, but it is the best we can do without access to company data. Other than Hidy & Hidy's datum for 1902, none of the *Histories* provide quantitative statistics on marketing, transportation, or production of natural gas.

Socony-Mobil started reporting gross production of natural gas in 1947. We estimate *net* gas production by applying the company's average net to gross proportion 1952-1956 (since we have both net and gross gas production data for 1950-1959). We use the same inference methodology to bridge between known net to gross ratios in the late 1950s and 1969/1970. The purpose is to estimate net natural gas sales for years when only gross production is reported by the company, and rather than reporting gross production under natural gas sales we wish to apply the bulk of the difference between gross and net production to company use of energy — at platforms and refineries, for example. For Socony's gas sales prior to 1947 we use the net asset value proportion discussed above, namely that we allocate to Socony 0.209 as much gas as SONJ marketed, starting in 1912 (based on each company's assumption of 9 and 43 percent of net asset value, and 9/43 = 0.209). Since Socony-Mobil's gas production grew faster than SONJ's, reaching 51 percent of SONJ in 1950, we increase the Socony/-SONJ allocation factor from 20.9 percent in 1911 to 48.2 percent in 1946.

Range of uncertainty (percent, quantity)

A significant source of underestimation of total sales and emissions is SONJ's reporting of gas made available for sale from 1980 to 1995 (rather than total marketed natural gas, as the company reports for 1962-1979 and 1996-2002). If we were to adjust this upwards based on the ratio of gas available for sale and total gas sold (which we have for later years), it suggests an under-estimate of 357 million tonnes of carbon.[29] Similarly, if we estimate the possible under-reporting of gas sold (that is, we have estimated net production made available for sales rather than the higher amounts of total gas marketed) by Socony-Mobil from 1947 to 1996 we get 419 million tonnes of carbon. Nonetheless, we stick with the data we have for all of these years and report emissions based on natural gas made available (SONJ-Exxon 1980-1995) and net gas production (Socony-Mobil 1952-1996). Any possible over-estimation for sales by either company 1900 to the advent of actual gas reporting in 1930 is very small compared to the possible 775.3 MtC of inferred under-estimation.[30] Aggregate uncertainty is thus 775.3 MtC, or +30.5 percent. Inasmuch as we believe that the data used consistently under-report actual total gas sales, we only assign a positive uncertainty of 30.5 percent. Additional positive uncertainties may come to light in a more comprehensive or company-supported investigation. In any case, we have a dataset on estimated sales and emissions (after deducting non-fuel uses) and a basis for non-marketed production available for each company's internal use of gas for processing, electricity generation, pipeline compressor stations, heating, and so forth.

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[29] For example, "net natural gas made available for sale" in 2000 was 10,343 million cubic feet per day (Mcf/d), whereas "natural gas sales" totaled 17,444 Mcf/d, or 69 percent higher. Multiplying the emissions from SONJ's gas made available for sale from 1980 to 1995 by 0.69 we get an additional 357 million tonnes of carbon.

[30] 776 million tonnes of carbon would add (776/2,549) 30 percent to total gas emissions for 1882-2002.

Venting & Flaring

Uses & carbon coefficients

Venting and flaring are two different sources of company emissions of carbon dioxide. Venting is the removal of unwanted carbon dioxide present in the natural gas produced, and this CO_2 is separated out from the wet gas (methane and natural gas liquids) at the well, production platform, or processing plant. Flaring refers to the combustion of natural gas that is either of too poor quality or too far from processing plants or markets to justify the expense of building pipelines to transport it. Globally, on the order of 4.6 percent of all the gas produced is flared.[31] Oil companies, including ExxonMobil, have reduced flaring at many facilities, yet it remains a large opportunity to reduce company emissions. Historic flaring rates were far higher, especially at the dawn of the oil era when natural gas was seen as oil's ugly duckling:

> *"In the early years of the petroleum industry, natural gas, like gasoline, was an unwanted child except in fields near large consuming centers. Wells that proved to be gas producers were disappointments only slightly less acute than dry holes. In many areas gas continued to be blown off and burned. The waste of gas resources was appalling, but science had not yet shown producers what might be done with this unwelcome byproduct, and most gas wells were not accessible to markets. Inadequate storage and transportation left little alternative but to apply the torch."* [32]

Statistics for the U.S. indicate that combined flaring rates were nearly one-quarter of marketed natural gas as late as 1940 (and even higher in previous decades). [33] We apply a declining flaring coefficient to account for ExxonMobil's and its predecessors' improved flaring practices and the opening of global markets. Flaring — rather than direct venting of methane — is done to avoid the risk of explosion and fire, and, from a climate perspective, it is preferable to convert methane into carbon dioxide through combustion, inasmuch as methane is 23 times stronger per unit mass compared to CO_2.[34]

Data, sources, and caveats

Venting: After consideration of several data sources and benchmarks, we estimate a venting rate (carbon emissions from CO_2 venting as a percent of natural gas consumption) of 1.76 percent, which we apply to carbon emissions from combusted natural gas marketed by ExxonMobil. This rate is applied to Standard Oil Company, SONJ-Exxon, and Socony-Mobil natural gas sales 1900-2002 (ignoring minor gas sales 1883-1899, as explained above).

Flaring: Considerations: ExxonMobil's operations are increasingly overseas, where flaring rates are typically higher than in the U.S. (especially offshore, Africa, and the Middle East); flaring rates have declined sharply over the last several decades; oil production facilities have been important sources of flaring; crude oil and oil products transport and storage continue to be sources of flared gas; finally, ExxonMobil's flaring rate is likely higher than industry leaders BP-Amoco and Royal Dutch/Shell Group. Inasmuch as flaring occurs throughout the supply chains of both natural gas and oil operations, we conclude that both hydrocarbon streams marketed by ExxonMobil should be bases of flaring emissions in the following manner:

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[31] Wang & Huang (1999) *A Full Fuel-Cycle Analysis of Energy and Emissions Impacts of Transportation Fuels Produced from Natural Gas*, p. 36, Argonne National Laboratory, Illinois; www.transportation.anl.gov/

[32] Gibb, George, & Evelyn Knowlton (1956) *History of Standard Oil Company (NJ), 1911-1927*, p. 70-71.

[33] Flaring rates from natural gas operations alone equaled 29 percent of marketed production in 1920, 24 percent in 1940, 4.4 percent in 1960, and 0.8 percent in 1990. Bureau of Mines (year unknown) *Minerals Yearbook*, Historical tables, M147-161, US Dept Interior; Energy Information Administration (2003) *Natural Gas Annual, 2002*, Table 3 & historical data; www.eia.doe.gov/oil_gas/natural_gas/data_publications/natural_gas_annual/nga.html.

[34] The IPCC revised the global warming potential (GWP) factor for methane (and several other gases in the last assessment). Houghton, J. T. et al (2001) *Climate Change 2001: The Scientific Basis*, Working Group One, Third Assessment Report (TAR), IPPC, Cambridge University Press, p. 388.

Flaring emissions (gas operations): seventy percent (0.70) of the global flaring rate estimated by the Carbon Dioxide Information Analysis Center (CDIAC) is applied to ExxonMobil's marketing of natural gas.[35] Thus, we credit ExxonMobil with a lower flaring rate than average industry practice, in part due the company's operations being located in more competitive markets, with more mature infrastructure, and a greater corporate emphasis on gathering and marketing *vs* flaring natural gas.

Flaring emissions (oil operations): 1.7 percent of carbon emissions from total petroleum sales 1882-2002. This flaring rate has declined over time, but we do not have a reliable dataset to vary this "constant." An oil industry competitor had flaring rates of 1.2 to 3.3 percent in 2002 (and showing a steady decline of the last several years), depending on which denominator (oil marketed or oil produced) the estimate is based.

Range of uncertainty (percent, quantity)

Venting: Given the vicissitudes of the data and the likelihood that venting rates were higher in earlier decades (and possibly but unconfirmably lower in recent decades) we assign an uncertainty of ±12 percent, or ±5.4 million tonnes carbon over the estimated total of 44.8 MtC for ExxonMobil and its predecessors for 1900-2002. *Flaring:* Due to the historic, technological, company-specific, and geographic unknowns about flaring practices, we assign a ±20 uncertainty factor, or 110.5 million tonnes of carbon on estimated flaring emissions of 552 MtC. *Combined venting and flaring* uncertainty is thus ±19.4 percent or 115.9 million tonnes of carbon on venting plus flaring emissions of 597 MtC.[36] ExxonMobil vented plus flared CO_2 equal 23.5 percent of emissions from combustion of marketed natural gas totaling 2,545 MtC for 1882-2002, and 3.4 percent of emissions from combustion of marketed oil plus natural gas totaling 17,334 MtC for 1882-2002.

We believe our venting and flaring estimates are within a reasonable and well-supported range. See the Venting and Flaring worksheet for detailed notes on methodology and results. As always, further research may benefit from detailed investigation of each company's venting and flaring data, historical data, or access to company records.[37]

Coal

Uses & carbon coefficients

Exxon invested in coal properties starting in the 1960s, commenced mining operations in 1970, and has mined 680 million tonnes of coal to date. SONJ-Exxon sold its Australian and Colombian interests in recent years, and ExxonMobil's production rate has dropped to about 3 million tonnes per year. Mobil's coal mining started in 1982 and ended with its divestment in 1991. As far as we can ascertain from annual reports, all of the mined coal was shipped to electric utility power plants, principally in Asia and the U.S., and hence we use a carbon

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[35] Marland, G., T.A. Boden, & R.J. Andres (2002) "Global, Regional, and National CO_2 Emissions," in *Trends: A Compendium of Data on Global Change*. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn, http://cdiac.esd.ornl.gov/trends/emis/tre_glob.htm

[36] Combined uncertainty of venting plus flaring emissions 1882-2002 is 115.9 MtC ÷ 597 MtC = ±19.4 percent.

[37] ExxonMobil reports decreased flaring activity in recent years (acknowledging that reductions are due to lower production offshore Nigeria). Reading from a small bar chart (no data is published), its 2002 "Flaring from Oil and Gas Production Operations" are about 480 million cubic feet per day (0.48 Bcf/d), or 175 Bcf/yr, which combusts to 2.61 million tonnes of carbon, and which is far less than our flaring estimate of 16.74 MtC in 2002. While our estimate includes, significantly, company-wide flaring, not just at oil and gas production facilities, future researchers should carefully review all of our flared gas estimation procedures. ExxonMobil Corporation (2003) *Corporate Citizenship Report*.

emission rate of 25.98 kg carbon per million Btu (average for U.S. utility-grade coal). The fraction of carbon in coal that is fully combusted to CO_2 is 99.0 percent.[38]

Data, sources, and caveats

As mentioned in the column header to Standard Oil (comment E10) on the Coal worksheet, we do not have coal production data for 1970-1983. We do know that SONJ was expecting to commence deliveries to Commonwealth Edison, a Chicago-based electric utility, in 1970, as well as planning further development of other owned or shared-equity coal reserves. We therefore use a straight-line growth from zero percent in 1969 to 100 percent in 1984 (the first year we have data from company annual reports), thus increasing in increments of 6.7 percent per year. Without data from SONJ-Exxon we do not know how close this inferred production tracks the company's actual coal production. However, even if we are off by 25 percent over the whole period 1970-1983 (one quarter of 92.9 MtC, or 23.2 million tonnes of carbon emitted), this equates to a company-wide uncertainty of ±5.9 percent of 394 million tonnes of carbon for ExxonMobil's relatively short history of coal mining.

Note: A small amount of double-counting of emissions occurs with the inclusion of ExxonMobil's coal production and thence combustion in coal-fired power plants. This arises when we also estimate emissions from the company's consumption of electricity around the world. This factor is deemed insignificant: ExxonMobil mined 582 million tonnes of coal from 1980 to 2000 compared to world coal production of 90.1 billion tonnes, giving an ExxonMobil share of 0.6 percent. This factor is further reduced by the fact that 63 percent of world electricity is generated in thermal (coal, oil, and gas) power plants.[39]

Range of uncertainty (percent, quantity)

We use the above uncertainty factor of ±5.9 percent, or 23.2 million tonnes of carbon of estimated 1970-2002 coal-related emissions of 394 MtC.

Company energy use

Uses & carbon coefficients

A company as large and complex as ExxonMobil — with 120 years of corporate history — uses vast amounts of electricity and fuels for a myriad of uses. We sample a few principal uses, and categorize them into "oil consumed," "natural gas consumed," and "electricity consumed." We combine SONJ-Exxon and Socony-Mobil as a single corporate entity for this section of the study. The company energy use is based on and is a fraction of the combined entity's total marketed oil products and natural gas. We apply the carbon coefficient for crude oil for this aggregation of multi-fuel uses and as a mid-point coefficient between lighter and heavier fractions of oil.[40] The natural gas coefficient is applied to company consumption of gas fuels. The carbon coefficient for electricity uses a calculated global average that is

[38] Energy Information Administration (2001) *Emissions of Greenhouse Gases in the United States 2000*, p. 106.

[39] Energy Information Administration (2001) *International Energy Annual 1999*, Table 6.3 (coal) & EIA (2003), *International Energy Annual 2001*, Table 6.3 (electricity). ExxonMobil's estimated electricity consumption is 0.17 percent of world net generation (24.9 billion kWh [TWh] ÷ 14,617 TWh, both year 2001).

[40] Heavy (bunker) fuels in tankers, diesel fuel in lorries and heavy equipment, natural gas liquids on production platforms, residuals and petroleum coke at refineries, etc. Future iterations of this work may lower this carbon coefficient to account for the natural gas liquids used in internal operations. NGLs (ethane C_2H_6, propane C_3H_8, butanes C_4H_{10}, etc) have a blended coefficient of 16.99 kg of carbon per million Btu (kgCMBtu; varies by year). We do not have data on NGL consumption by ExxonMobil. If we assume that one-quarter of "oil" consumption is 16.99 kgCMBtu and three-quarter is 20.25 kgCMBtu (crude oil coefficient), then the final coefficient is 19.44 kg of carbon per million Btu. We did not apply a combustion factor (typically 99 percent for liquid fuels).

weighted toward the higher carbon-intensity of U.S. and Asian electric systems. Unlike most sources, we include the transmission and distribution losses in the calculation so that the full emission of carbon dioxide at the power plants is on the basis of kWh *consumed* rather than per kWh generated. Thus calculated, the "weighted global electric grid" emits 0.1828 kg of carbon per kWh consumed.[41] We did not estimate fuel and electricity used to mine or process coal, to transport coal by rail or conveyor, or to ship coal to international destinations.[42]

Data, sources, and caveats

We use other data sources, proxy datasets, and related data to estimate oil, gas, and electricity consumption for three principal activity areas: upstream facilities, refineries, and transport. Given the variety and complexity of facilities and uses of energy within ExxonMobil — not to mention our lack of measured company energy consumption data — readers are cautioned about the relatively high degree of uncertainty of the estimates presented in this section of the study. However, we have investigated in some detail the operations of an integrated oil company, and refer readers to the worksheet on Company Energy Use for the calculations, methods, assumptions, and proxy data used.

Oil: Oil products are used extensively in refinery operations, as fuel to generate electricity on production platforms, and in transportation (in VLCC tankers from far-flung operations to refineries, and in lorries to petrol stations, for example). The equivalent of 9 percent of the carbon emissions from each company's marketed oil products is allocated to emissions from oil products consumed for company operations. Note: we do not include company use of oil from 1882 through 1911, since the estimated marketed oil products for those years are based on inputs to Standard Oil refineries as thus already include fuels used in internal operations.

Natural gas: Natural gas is also used throughout company operations from exploration to delivery, but predominantly as pipeline fuel, in compressor stations, on production platforms, and as refinery input to both gas processing facilities and oil refineries. We allocate 85 percent of the difference between gross and net production of natural gas to each company's own use and thus internal emissions (first allocating 15 percent of the gross minus net as repressuring gas, which is thus sequestered in oil fields).

Electricity: Electricity consumption is ubiquitous and used in tens of thousands of facilities in nearly 200 countries around the world. We estimate electricity use in upstream facilities, pipelines, refineries, gas processing, at 40,000+ service stations and thousands of other wholesale and retail facilities, and in company buildings such corporate headquarters, laboratories, field offices, foreign offices, etc. We'll describe two of several elements of company use of electricity (see the worksheet for other company electricity uses and emissions):

- Refinery operations: U.S. refineries purchased 34.7 billion kWh and delivered 6.31 billion barrels of oil products in 2002, giving an electricity consumption rate of 5.51 kWh per barrel refined. To account for electricity consumed in pipeline operations, gas processing plants, and related uses, we increase this factor to from 5.51 to 7.00 kWh per barrel of oil products marketed as an estimate of ExxonMobil's total upstream electricity consumption. While Exxon-

[41] Carbon emissions vary greatly around the world (high in the US, UK, Germany, Russia, and the Middle East, low in Canada and Norway). The global average is ~0.901 as carbon intensive as the U.S. electricity mix (2000), or 1.64 lbs CO_2 per delivered kWh x 0.901 x 0.45359 kg/lb/3.667 CO_2/C = 0.1828 kgC/kWh consumed. Heede calculations; Thomas *et al* (2000) *The GHG Indicator: Guidelines for Calculating Greenhouse Gas Emissions for Businesses & Non-commercial Organisations*, UNEP, Geneva, p. 47, which estimates carbon emissions for several countries and world regions; world average = 0.466 kg CO_2 per kWh = 0.1271 kgC/kWh; this, however, does not include transmission and distribution losses, whereas our estimate does. T&D losses average around 6-7 percent in the U.S., though far higher in most developing countries.

[42] While not estimated, emissions from energy inputs to mining and delivering 775 million tonnes of coal (1970-2002) is not trivial. Aback-of-the-envelope estimate: 4-8 percent of emissions from burning the stuff = 393.4 million tonnes of carbon x 0.04 and 0.08 = 15.7 to 31.5 MtC over the companies' coal mining history.

Mobil has added 1,400 MW of cogeneration capability worldwide since 1990 — which reduces purchases of steam and electricity, improves efficiency, and emissions of carbon dioxide — we do not have sufficient fuel and geographic data to adjust our estimated electricity-related emissions.[43] In recognition of the fact that consumption of electricity has expanded six-hundred-fold since the turn of the century we apply an electricity intensity factor: that is, we only apply one percent of the electric intensity starting in 1903 compared to 2002, adding one percent per year up to 2002.[44]

- Service stations and other wholesale and retail operations: ExxonMobil operates more than 40,000 service stations. We assume that half are high-intensity stations, with high lighting levels and duty cycles, a multitude of pumps, refrigeration units, compressors, ventilation fans, cooling equipment, POS machines, coffee makers, and miscellaneous plug loads. These loads average, according to measured (non-ExxonMobil) data, 147,300 kWh per year. We assume further that the other half of ExxonMobil's 40,000 service stations are low-intensity sites and consume one-quarter as much electricity per site. Total = 2.95 + 0.74 = 3.69 billion kWh. We add an estimated 0.80 billion kWh for other downstream facilities, and for a total of 4.49 billion kWh in 2002. Divide by 2.83 billion bbl of oil products marketed by ExxonMobil in 2002, and the electricity consumption rate equals 1.58 kWh per marketed barrel. This is again diluted by our declining electricity intensity index back to 1903.

Range of uncertainty (percent, quantity)

Considering the variety of assumptions, use of proxy data, lack of corporate specifics such as million square feet of office space around the world, details on pipeline fuels, fuel-rates by crude carriers, and a general lack of measured data from ExxonMobil, we assign an uncertainty range of ±20 percent, or ±390.7 million tonnes of carbon on estimated company energy-related emissions of 1,954 MtC. We have a high degree of confidence that actual emissions lies within our error bar.

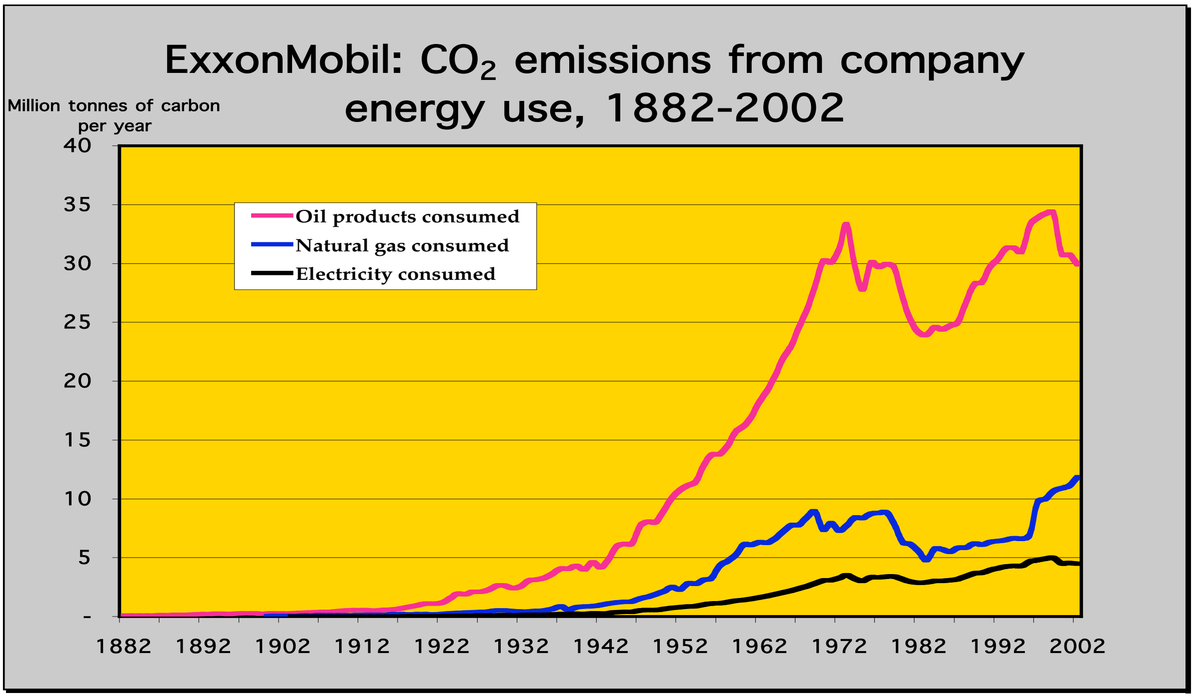

Figure 3. Heede (2003) *ExxonMobil Corporation: Emissions Inventory 1882-2002*, Data are not stacked.

[43] ExxonMobil (2003) *Corporate Citizenship Report.* A 0.60 availability factor x 8,760 hrs/yr x 1,400 MW → 7.36 billion kWh per year, or 15.24 billion kWh at ExxonMobil's total installed capacity of ~2,900 MW; this latter datum equates to 62 percent of estimated total XOM electricity consumption of 24.5 billion kWh in 2002.

[44] Net generation in the United States in 1902 totaled 5.97 billion kWh, and by 2002 it had expanded to 3,719 billion kWh, or 623 times as much. By 1912 the ratio had shrunk to 24.75:3,719, or 1:150, and by 1922 it was 1:61. EIA (2002) *Annual Energy Review 2001*, p. 221; Bureau of the Census (1976) *Historical Statistics of the United States, Colonial Times to 1970*, Dept of Commerce, Series S 32-43. While this suggests that we scale down from 2002 by a faster factor, we retain the one percent per year electricity function inasmuch as industry and commerce were early adopters of lighting and electrical machinery.

Comparing the results of this study with GREET and ExxonMobil "data"

The GREET model (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) suggests some general parameters for petroleum, natural gas, and electricity inputs to various stages in the fuel cycle — from wells to wheels, as the principal investigators at Argonne call it. We incorporate some of the factors developed for the GREET model, particularly in the oil product inputs section and the energy used to transport crude oil and the refined products to market.

Comparison #1: GREET model results:

In GREET, energy inputs to production of transportation fuels (such as gasoline and diesel) averages an adder of 4.25 percent (219 Btu per mile) for the production and shipping of crude oil to refineries, plus and additional 19.9 percent (1,026 Btu/mile) for refinery operations and delivery to ultimate consumers (this is above and beyond the energy contained in the fuel (5,156 Btu/mile), which means that the total adder is **24.15 percent**).

Our results: the total oil, gas, and electricity inputs in 2002, and measured in terms of the emitted carbon: 46.26 million tonnes of carbon, divided by the carbon emitted by the combustion of ExxonMobil's products sold, also in 2002: 399.05 MtC, or 11.59 percent. Our adder is thus very conservative compared to that suggested by the GREET model (24.15 percent *vs* 11.59 percent). Adjusting up to the GREET model's adder would increase ExxonMobil's internal emissions to 96.39 MtC. (Note: GREET includes items that we include in separate worksheets, namely CO_2 venting and natural gas flaring; GREET considers methane leakage, but not in the datum cited above). If we add these items to internal emissions, we get 46.26 MtC for internal emissions + 18.49 MtC in venting and flaring = total of 64.75 MtC, which is considerably below GREET's suggested 96.39 MtC. This total adder is now 64.75 MtC divided by 417.54 MtC = 0.1551, or **15.51 percent**, *considerably lower than GREET's 24.15 percent*. ExxonMobil, incidentally, contributed to the development of ANL's GREET model.

Source: Michael Q. Wang, Argonne National Laboratory, www.transportation.anl.gov/greet/index.html, and personal communication 18Jul03.

Comparison #2: XOM emissions inventory:

ExxonMobil has not published any substantive details on greenhouse gas emissions. A few tidbits are posted on their website (listed below) and in Doug Cogan's report, in which he cites ExxonMobil emissions in 2000 at 122.9 million tonnes (presumably CO_2 and CO_2-equivalent of methane). On Cogan's p. 92: "XOM says 13% of CO_2 emissions from its petroleum products come from production. Customer use accounts for the other 87%."

Let's compare ExxonMobil's datum (even though we know little about sources included, their boundary definition [beyond "CO_2 and methane from global upstream, refining, and chemicals operations," Cogan, p. 92], or their accounting practices) with our results for 2000 (in units of carbon dioxide, not carbon):

	XOM	**This study***
Company emissions:	122.9 $MtCO_2$	379.1 $MtCO_{2\text{-equivalent}}$
Product emissions:	822.5 $MtCO_2$**	1,463.3 $MtCO_2$

*Venting + flaring = 18.49 MtC = 67.80 $MtCO_2$; company energy use = 46.26 MtC = 169.64 $MtCO_2$; methane = 6.16 million tonnes of methane = 141.68 $MtCO_{2\text{-equivalent}}$; Total = 379.12 $MtCO_2$-equivalent. "Customer" (XOM term) or "external" emissions: this study: 399.05 MtC = 1,463.3 million tonnes CO_2.

** Simple conversion on XOM's cited 87 to 13 rule: 122.9 $MtCO_2$ x (87/13) = 822.5 $MtCO_2$.

Note: we are not comparing similar accounts: XOM may be carbon dioxide only (whereas we include fugitive methane), XOM's is based on company production only (our data is for marketed production), XOM data may not deduct for carbon sequestered in non-combusted lubricants and other specialty products, XOM data may not even include natural gas or coal production. We simply cannot tell what the sparse ExxonMobil data includes.

Cogan, Douglas (2003) *Corporate Governance and Climate Change: Making the Connection*, by Investor Responsibility Research Center, Washington, for Coalition for Environmentally Responsible Economies (CERES), Boston; PDF: www.ceres.org/pdf/ceres_cg_rprt.pdf

ExxonMobil publications on climate and greenhouse gas emissions:

www.exxonmobil.com/Corporate/Files/Corporate/greenhouse.pdf

www.exxonmobil.com/corporate/notebook/climate/corp_N_climatedetails.asp

Corporate Citizenship Report, see www.exxonmobil.com/corporate/Newsroom/Publications/Corp_P_Citizenship2002.asp (see section on environmental performance), May 2003.

Fugitive Methane

Uses & carbon coefficients

Methane is emitted from natural gas production and pipeline systems, refineries and gas processing facilities, from crude oil and oil products tank farms (tank flashing losses), from incomplete combustion in gas flaring (the industry assumption is 2 percent incomplete combustion, but it is typically less than 1 percent),[45] and in minute quantities from millions of valves, flanges, and seals in gas handling equipment.

The IPCC has revised its global warming potential (GWP, 100 year time horizon) of methane relative to carbon dioxide to 23 x CO_2 (from 21 x CO_2 previously). In the U.S., methane accounts for 9.3 percent of six-gas emissions (2001), although globally fugitive methane account for closer to 20 percent of total emissions (including biogenic sources).

Data, sources, and caveats

Fugitive losses of methane as well as deliberate wastage of natural gas (which is typically about 90-96 percent methane) were much higher per unit of production of both gas and oil before and after the turn of the 19^{th} Century. While we have no quantitative national or corporate data by which to increase the methane emissions rate in Standard Oil's early decades, it is possible that our calculations dramatically under-estimate the amounts of methane released. The overall amounts from 1882-2002 would not be much affected — perhaps by a few million tonnes of methane over the first decades — but the significance of simply "blowing off" natural gas could be far more dramatic in terms of the high global warming potential of directly released methane to the atmosphere. Here again, however, we have no quantitative data, nor do we have qualitative information on the practice of flaring *vs* direct release of natural gas in the early years of the petroleum industry.

Recent air sampling in the southcentral U.S. — up to 1,200 km from the oil and gas production and processing centers in Colorado, Oklahoma, Kansas, Texas, and Louisiana — show elevated levels of methane, ethane, butane, and propane.[46] The authors suggest that leakage from regional oil and gas facilities as well as natural seepage may release 4-6 million tonnes more methane than previously thought (estimated emissions from oil and gas sector, including combustion systems, is 8.1 million tonnes of methane). This will spur a careful review of U.S. methane emissions, and future researchers may find that our estimated emissions from ExxonMobil facilities are very conservative.

Fugitive methane, flaring operations: Our estimate is based on the methodology developed by Sterns & Kaufman, and we quote:[47] “A ratio of 0.267 metric tons of CH_4 per metric ton of CO_2 released from flaring was assumed, for estimates from 1950 through 1994; that is, for each year t:

$$CH_{4t} = 0.267F_t,$$

where CH_4 and F are metric tons of methane and carbon in carbon dioxide from flaring, respectively. The flaring data are from Marland & Boden (1997).” See the

[45] American Petroleum Institute (2001) *Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry*, URS Corporation, Austin, TX, p. 4-16.

[46] Katzenstein, Aaron S., Lambert A. Doezema, Isobel J. Simpson, Donald R. Blake, and F. Sherwood Rowland (2003) “Extensive regional atmospheric hydrocarbon pollution in the southwestern United States,” *Proceedings of the National Academy of Sciences*, vol. 100:11975-11979.

[47] Stern, David, & Robert Kaufmann, *Methane Emissions 1860 to 1994*, US Dept of Energy, at Carbon Dioxide Information Analysis Center, Oak Ridge, TN: http://cdiac.esd.ornl.gov/

comments to cells and data series for elaboration of the more complex equation for fugitive methane emissions estimates for 1882-1949.

Fugitive methane, oil and gas supply systems: Again based on the Sterns & Kaufman methodology, from which we quote: “Calculated by assuming a coefficient of 0.0167 metric tons CH_4 per metric ton of carbon emitted as carbon dioxide from natural gas consumption; that is, for each year t:

$CH_{4t} = 0.0167\ C_t$”

Fugitive methane, coal mining: We multiply Sterns and Kaufman's global methane emissions by the fraction of world coal produced by ExxonMobil’s coal operations (equity share only). We quote from Sterns & Kaufman: “Methane emissions in metric tons were estimated differently for three time periods (1860-1948, 1949-1954, and 1955-1984, and 1985-1994), based on coal production data for the world, the U.S., the U.K., and the rest of the world.” See cell comments in the Methane emissions worksheet for details on this phased formula.

Range of uncertainty (percent, quantity)

We assign an uncertainty range of ±10 percent, or 19.9 $MtCH_4$ on total estimated fugitive methane emissions from ExxonMobil operations of 199.4 $MtCH_4$ for 1882-2002. Since the larger proportion of energy-related fugitive methane is from coal mining — to which ExxonMobil’s contribution is small relative to its oil and gas sources — it is no surprise that the company’s total methane emissions is a smaller proportion of total anthropogenic methane than the company’s share of carbon dioxide emissions.

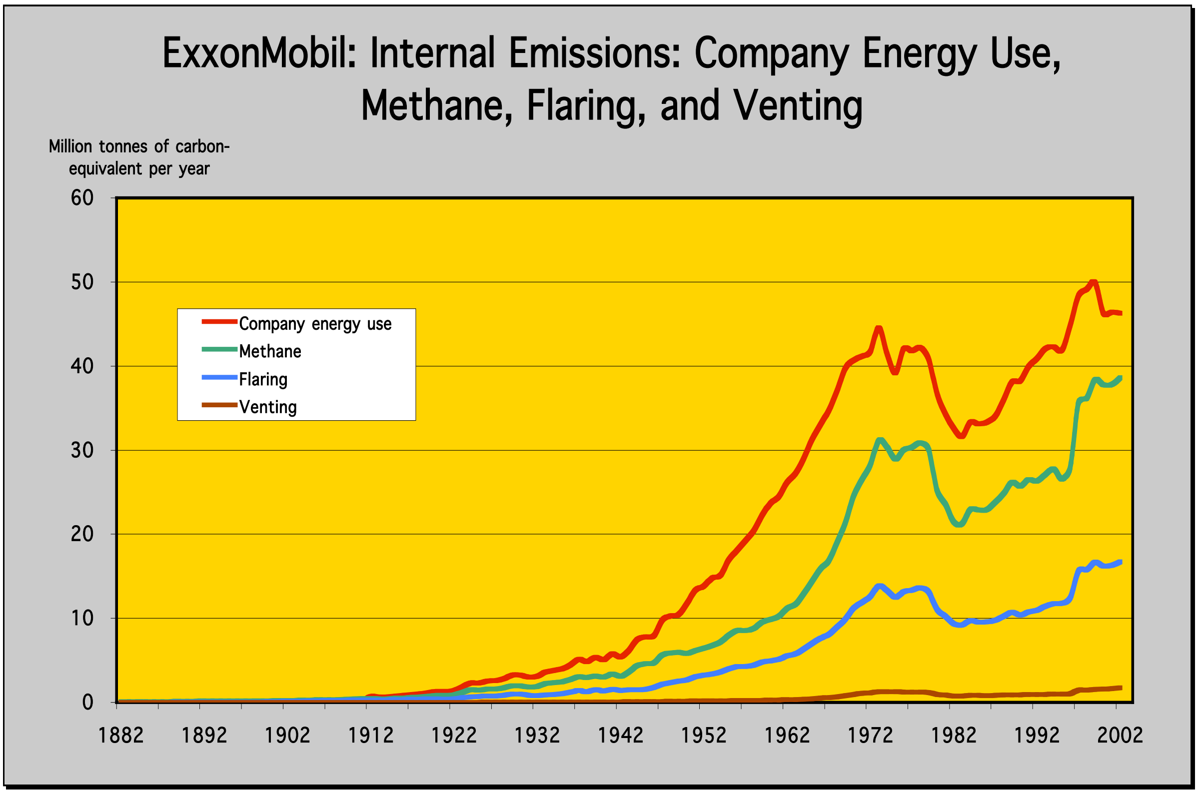

Figure 4. Internal emissions of carbon dioxide and methane from company energy use, fugitive methane, flaring of natural gas, and direct venting of carbon dioxide. (Data are not stacked.)
Heede (2003) *ExxonMobil Corporation: Emissions Inventory 1882-2002*, spreadsheet charts.

Uncertainty estimates

We summarize uncertainty ranges for every source of greenhouse gas emissions surveyed in this study in Table 3. Bear in mind that this sums 120 years of corporate history, energy marketing, and emissions of carbon dioxide and methane, and we have not assessed the uncertainty over *time*. Estimates for recent years — which are quantitatively larger — may, or may not, have a higher degree of certainty, depending on too many factors to summarize here. In any case, the overall uncertainty is +8.3/-4.7 percent on total estimated emissions of 21,532 million tonnes of carbon-equivalent. This also means that we have a high confidence that the "actual" number, if any other team can ascertain it, will fall within the upper and lower bounds we estimate below. We have not, however, done a quantitative review of likely conservatisms and liberalisms. We have routinely selected conservative estimates, noted data-gaps, and described the potential under-estimates from shifting definitions in the cited data. In addition, the emissions sources excluded from this study — such as energy inputs to coal mining, fugitive refrigerants and related compounds, all nitrous oxide sources, and numerous sources of carbon dioxide emissions — are likely to be quantitatively more significant, if included in future inventories, than the uncertainty ranges summarized below. (See the Boundary Table, p. 6, for details of omitted emissions.)

Table 3.
Uncertainty estimates and high/low emissions

Emissions source	Emissions (MtC)	Uncertainty (percent)	Uncertainty (MtC)	Low estimate (MtC)	High estimate (MtC)
Kerosene, jet fuel	786	±2	±15.7	770	802
Gasoline	4,146	±2	±82.9	4,063	4,228
Diesel	4,114	±2	±82.3	4,031	4,196
Heavy fuels	3,349	±2	±67.0	3,282	3,416
Special products	1,074	±6	±64.4	1,010	1,138
Aggregate oil	1,323	±4	±52.9	1,270	1,376
Natural gas	2,545	-0, +30.5	-0, +775.3	2,545	3,320
Venting + flaring	597	±19.4	±115.9	481	713
Coal	394	±5.9	±23.2	371	417
XOM energy use	1,954	±20	±390.7	1,563	2,344
Total carbon	20,281	+8.24/-4.41	1,670	19,386	21,952
Methane	199	±10	±19.9	180	219
Methane (C-equiv.)	1,251	±10	±125.1	1,126	1,376
Total (C-equiv.)	21,532	+8.34/-4.74	1,795	20,512	23,327

MtC = million metric tonnes of carbon. Data for total ExxonMobil emissions 1882-2002. Columns may not add due to rounding.

These expressions of uncertainty have not been calculated on the basis of standard statistical practice. Rather, they have been assigned in order to give the reader as accurate a sense as possible of the uncertainties associated with each category, of the comparative uncertainties of the categories, and of the overall uncertainties. While some readers may take issue with a few possible over-estimates, such as our flaring data *vs* ExxonMobil's partial estimate discussed previously, we have confidence that we are far more likely to have, in aggregate, *under-estimated* rather than over-estimated total emissions by ExxonMobil Corporation and its predecessors.

Coefficients and carbon factors

Table 4.

Carbon emission coefficients used in this report

Kerosene	19.72 kg carbon per million Btu (21.537 lbs CO_2 per gallon; 135 kBtu per gallon; 159.535 lbs CO_2 per million Btu);
Jet fuel	19.33 kg carbon per million Btu (21.095 lbs CO_2 per gallon; 156.258 lbs CO_2 per million Btu);
Gasoline	19.38 kg carbon per million Btu (19.564 lbs CO_2 per gallon; 125.1 kBtu per gallon, 156.425 lbs CO_2 million Btu);
Naphtha	19.86 kg carbon per million Btu (160.553 lbs CO_2 per million Btu);
Diesel, home heating oils	19.95 kg carbon per million Btu (22.384 lbs CO_2 per gallon; 138.7 kBtu per gallon; 161.386 lbs CO_2 per million Btu);
Heavy fuels	21.49 kg carbon per million Btu (26.033 lbs CO_2 per gallon; 138.7 kBtu per gallon; 173.906 lbs CO_2 per million Btu);
Crude oil (aggregate products)	20.25 kg carbon per million Btu (22.612 lbs CO_2 per gallon, 163.71 lbs CO_2 per million Btu) (we use this factor for figuring emissions for aggregated oil sales).
Natural gas (pipeline)	14.48 kg carbon per million Btu (1,027 Btu per cubic foot; 120.593 per 1000 cubic feet; 117.080 lbs CO_2 per million Btu).
Natural gas liquids	16.99 kg carbon per million Btu (137.351 lbs CO_2 per million Btu).
Coal (U.S. utility coal)	25.98 kg carbon per million Btu (4,276.9 lbs CO_2 per short ton; 210.0 lbs CO_2 per million Btu).
Electricity (U.S.)	0.2029 kg carbon per delivered (consumed) or saved kWh.
Electricity (global)	0.1828 kg carbon per delivered (consumed) or saved kWh.

Energy Information Administration (1998) *Voluntary Reporting of Greenhouse Gases, 1997*, Appendix (oil); www.eia.doe.gov/oiaf/1605/frntvrgg.html & www.eia.doe.gov/oiaf/1605/gg97rpt/appb.html. EIA (2003) *Annual Energy Review 2001*, pp. 337, 349 (natural gas & coal). Electricity calculation by Heede, based on EIA statistics. Note: UNEP's estimate of global average carbon intensity of electricity is lower (0.1271 kg carbon per kWh), but does not include transmission and distribution losses. We account for the fact that the preponderance of ExxonMobil consumption of electricity is in carbon-intensive grid regions (U.S., especially Texas and Louisiana, and Asia) in our modified global average of 0.1828 kg carbon per kWh consumed.

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