Early oil industry knowledge of CO_2 and global warming

To the Editor — In a seminal 1960 article in the journal *Tellus*, Charles Keeling reported that the concentration of atmospheric CO_2 at the South Pole was rising at a rate "nearly that to be expected from the [global] combustion of fossil fuel"[1]. His measurements, begun in 1957, allowed him to start constructing the famous Keeling curve — the continuous, direct record of rising CO_2 levels around the globe caused primarily by the burning of fossil fuels. Yet archival documents show that even before Keeling published his measurements, oil industry leaders were aware that their products were causing CO_2 pollution to accumulate in the planet's atmosphere in a potentially dangerous fashion. And when US President Lyndon Johnson's Science Advisory Committee warned of global warming in 1965, the petroleum industry's main trade association, the American Petroleum Institute (API), relayed the warning to its members.

In 1954, the geochemist Harrison Brown and his colleagues at the California Institute of Technology submitted a research proposal to the API entitled "The determination of the variations and causes of variations of the isotopic composition of carbon in nature." The scientists proposed the use of new mass spectrometers to investigate the ratio of carbon-12 to carbon-13 in terrestrial, marine and mineral systems to understand geological and biological carbon cycling.

The team had already carried out preliminary work, including on tree rings of various ages. "Perhaps the most interesting effect concerning carbon in trees which we have thus far observed," the researchers reported to the API, "is a marked and fairly steady increase in the $^{12}C/^{13}C$ ratio with time." The results indicated that fossil fuels had caused atmospheric CO_2 concentrations to rise by about 5% over the past century[2]. Brown's estimate was quite accurate: from 1854 to 1954, global CO_2 concentrations had risen by 10% (from around 285 to 313 ppm)[3], with about 4% of that from fossil fuels and the remainder from deforestation and other land-use changes[4].

That same year, in 1954, the Yale ecologist George Hutchinson suggested using carbon isotopes to measure atmospheric CO_2 from fossil fuels[5]. However, Brown's research proposal, reproduced in Fig. 1 and never before noticed by historians, shows that such measurements had already been performed — and reported to petroleum industry leaders.

In 1955, the API began funding the proposed research at Caltech under the name Project 53. The project focused on uranium–lead dating, yet work on carbon continued, at least for a time: later that year, the researchers told the API that they were using their mass spectrometer to make around 2,300 measurements on CO_2 per year[6]. The results were not published.

Others began examining fossil fuel emissions using carbon isotopes in tree rings. Hans Suess, in 1955, gave a low estimate of atmospheric fossil carbon[7] of less than 1%. Suess's work was expanded in 1957 by H. R. Brannon of Humble Oil Company (now ExxonMobil), who found higher concentrations of 3.5%. Brannon knew of Harrison Brown's unpublished work, compared results and found that they agreed[8].

Perhaps the most interesting effect concerning carbon in trees which we have thus far observed is a marked and fairly steady increase in the C^{12}/C^{13} ratio with time. Since 1840 the ratio has clearly increased markedly. This effect can be explained on the basis of a changing carbon dioxide concentration in the atmosphere resulting from industrialization and the consequent burning of large quantities of coal and petroleum. If this explanation were correct, the carbon dioxide content of the atmosphere today would be about 5% greater than it was a century ago.

Fig. 1 | Excerpt of research proposal to the API from Harrison Brown and colleagues in 1954. The proposal informed the API that fossil fuels had caused atmospheric CO_2 levels to rise by about 5% over the last 100 years. Image reproduced from ref. [2], Caltech Archives.

This report unquestionably will fan emotions, raise fears, and bring demands for action. The substance of the report is that there is still time to save the world's peoples from the catastrophic consequence of pollution, but time is running out.

One of the most important predictions of the report is that carbon dioxide is being added to the earth's atmosphere by the burning of coal, oil, and natural gas at such a rate that by the year 2000 the heat balance will be so modified as possibly to cause marked changes in climate beyond local or even national efforts. The report further states, and I quote: ". . . the pollution from internal combustion engines is so serious, and is growing so fast, that an alternative nonpolluting means of powering automobiles, buses, and trucks is likely to become a national necessity."

Fig. 2 | Excerpt of address given by API President Frank Ikard at the organization's annual meeting in 1965. Ikard informed the API's membership that the US President's Science Advisory Committee had predicted that fossil fuels would cause significant global warming by the end of the century. Reproduced from ref. [11], American Petroleum Institute.

A few years later, in 1959, petroleum industry leaders were notified of the danger of CO_2 accumulation by the physicist Edward Teller, who warned them of global temperature and sea-level rise by the end of the century[9]. Thus, even before early portions of the Keeling curve were published in 1960, leaders of the API and other segments of the oil industry were informed that fossil fuel products were causing atmospheric CO_2 concentrations to rise, and that such a rise was potentially dangerous.

When that danger was brought to US President Lyndon Johnson's attention by his Science Advisory Committee's *Restoring the Quality of Our Environment* report in 1965, the petroleum industry took notice[10]. Three days after the report's publication, API president Frank Ikard addressed industry leaders at the organization's annual meeting, saying, "One of the most important predictions of the report is that carbon dioxide is being added to the Earth's atmosphere by the burning of coal, oil, and natural gas at such a rate that by the year 2000 the heat balance will be so modified as possibly to cause marked changes in climate beyond local or even national efforts"[11]. Ikard did not dispute the links between fossil fuels, CO_2 and global warming. "The substance of the report," he summarized, "is that there is still time to save the world's peoples from the catastrophic consequence of pollution, but time is running out." This communication, reproduced in Fig. 2, has also remained unnoticed by historians until now.

These archival discoveries add to the growing body of information regarding fossil fuel producers' knowledge of climate science over time[12]. Such information may assist in understanding the history of climate policy efforts and assessing the responsibilities of fossil fuel producers today[13]. ❐

Benjamin Franta
Department of History, Stanford University, Stanford, CA, USA. e-mail: bafranta@stanford.edu

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Antarctic ice losses tracking high

To the Editor — Satellite observations show that ice losses from Antarctica have accelerated over the past 25 years[1]. Since 1992, the continent has contributed 7.6 mm to global sea levels, with 40% of this occurring in the past 5 years. Glaciers draining West Antarctica have retreated, thinned and accelerated due to ocean-driven melting at their termini, and the collapse of ice shelves at the Antarctic Peninsula has led to reduced buttressing and increased ice discharge[2]. Of the 3.2 mm yr^{-1} sea-level rise (SLR) measured during the satellite era[3], Antarctica has contributed 0.27 mm yr^{-1}. The magnitude of SLR from Antarctica is the largest source of uncertainty in global sea-level projections, which are key to appropriate climate change policy.

Projections of the global sea-level budget in the Fifth Assessment Report (AR5) of the IPCC[3] are driven by emission scenarios that account for permutations of the physical, socioeconomic and legislative factors that will shape the century-scale increase in global temperature. These representative concentration pathways (RCPs) allow for unabated (RCP8.5), stabilizing (RCP6.0, RCP4.5) and decreasing (RCP2.6) emissions, in addition to the Special Report on Emissions Scenarios (SRES) used in the AR4[4]. The scenarios predict between 280 and 980 mm of global mean SLR by 2100, around a central estimate of 570 mm. The contribution from Antarctica is uncertain, due to challenges in simulating the regional meteorology and the ice sheet's dynamical response, and falls within −75 and +160 mm.

The accuracy of sea-level predictions is important because there are consequences associated with under- or overestimating the societal response required. Recent advances in the capability of ice-sheet models have improved the skill of simulations when compared to historical trends[5]. In AR5, the Antarctic regional meteorology was determined from an ensemble of global coupled atmosphere–ocean models[6], and the ice-sheet models incorporated full numerical descriptions of ice flow and grounding-line migration[3]. The expected range of dynamical ice loss was assessed through depth-averaged ice flow simulations[7]. When combined, these contributions produce the lower, central and upper estimates of sea-level change due to Antarctica reported in AR5 (Fig. 1).

Because the satellite record of Antarctic ice-sheet mass balance[1] now overlaps with a decade of the AR5 projections[3], we can perform a meaningful comparison between the measured and predicted change (Fig. 1). Between 2007 and 2017, satellite observations show that Antarctica lost 1,883 Gt of ice, equivalent to a contribution of 0.55 mm yr^{-1} to global SLR. This value is around 30 times greater than the IPCC's lower estimates, which predicted an average contribution of just 0.02 mm yr^{-1}, and is now at odds with the satellite record. The rate of ice loss is also 80% higher than the AR5 central projections (0.36 mm yr^{-1}) as a consequence of the observed acceleration, and is in fact closest to the upper range (0.68 mm yr^{-1}).

If Antarctic ice losses continue to track the upper range of the AR5 projections, the continent will contribute 151 mm, on average, to global sea levels by 2100. When compared with the central estimate (50 mm), this amounts to an extra 101 mm of SLR. An even greater contribution is possible, because the AR5 projections did not account for the effects of increasing emission concentrations on ice-sheet dynamics, or for the possible impacts of processes such as ice cliff instabilities. Additional ice losses from Antarctica are of particular concern for cities in the Northern Hemisphere, where