Senate Standing Committee on Economics
ANSWERS TO QUESTIONS ON NOTICE
Innovation, Industry, Science and Research Portfolio
Budget Estimates Hearing
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AGENCY/DEPARTMENT: INNOVATION, INDUSTRY, SCIENCE AND RESEARCH – CHIEF SCIENTIST

TOPIC: Climate Change –human action

REFERENCE: Question on Notice (Hansard 1 June 2009, E 99)

QUESTION No. BI-87

Senator ABETZ—The largest portion of the change in the CO2 levels is due to human action. Are you able to assist the committee as to what the body of scientific knowledge is? You may need to take that on notice. I could accept that you would not necessarily have this figure in your back pocket, but if you do it would be great. You say that the largest portion of the change is due to human action. What proportion would you say is due to human action? Would you put it at 51 per cent or 80 per cent? Can we quantify it in any way?
Prof. Sackett—It can be quantified. As in most good science, it has a range. In fact, what science does is not only tell one a best estimate but give some uncertainty around that, or rather a degree of certainty around the range in which those numbers are believed to lie. I would not like to state that in a forum such as this. I would like to take that on notice.

ANSWER

The proportion of the change in atmospheric CO_2 (carbon dioxide) concentration that is due to human (anthropogenic) action depends on the timescale over which one measures the change. A large body of scientific evidence indicates that nearly all of the long-term increase of more than 35% (107ppm, from 280 to 387ppm) in atmospheric CO_2 concentrations since 1800 is due to anthropogenic causes. Natural causes over this period contribute short-term variability on time scales of several months to a few years with transient amplitudes of about 10 ppm or less. These conclusions rest on data arising from ice core analysis, direct atmospheric CO_2 measurements, careful accounting of the net amount of CO_2 released into the air by humans, and isotopic ``fingerprint'' analysis of atmospheric and marine CO_2, In sum, at any given moment in the present, about 90-99% of the industrial era *change* of 107ppm in the atmospheric CO_2 concentration is due to human activity. The variability of this percentage is due to short-term, oscillatory natural causes. The much larger, steady long-term increasing trend is due to human activities. I will now summarize the body of evidence that supports these conclusions.

<u>The baseline data: Atmospheric CO_2 over millennia during the pre-industrial era</u>

Over a period stretching over most of the Holocene from more than 11,000 years ago to the year 1750, CO_2 concentrations have been stable at 280 ppm, with variations of 20ppm or less (Etheridge *et al.* 1996; Etheridge *et al.* 1998; Indermühle *et al.*, 1999, Sabine *et al.* 2004a). The primary source of atmospheric CO_2 concentration data during this period comes from

analysis of the composition of air enclosed in bubbles in ice cores from Greenland and Antarctica. The measured variation of no more than 20 ppm (ie, 7% of pre-industrial levels, or about 5% of current levels) during this time frame is judged to be largely due to non-human sources.

The data: Atmospheric CO_2 over the whole of the Industrial era

Since the beginning of the 19th century, carbon dioxide in the atmosphere has risen substantially. The primary source of data for CO_2 concentrations during this period comes from ice core analysis and, since the late 1950s, also from direct measurements of atmospheric CO_2, most notably from carefully calibrated observing stations at Mauna Loa, Hawai'i (Keeling *et al.*, 1976; Thoning *et al.*, 1989; Conway *et al.*, 1994) and Cape Grim Tasmania (Francey 2005). These records are in agreement, and show that by 1958 atmospheric CO_2 had risen to 315ppm, and then rose even more sharply to the present value of 387ppm. It is this change of 107ppm over the past 200 years that is attributed almost entirely to human activity, a change more than five times the variability in atmospheric CO_2 from the end of the last ice age to the dawn of the industrial age.

The accounting: Net anthropogenic contribution to atmospheric CO_2

The main evidence that human activities are responsible for the increased CO_2 during the industrial era comes from an accounting of the actual amount of carbon dioxide released due to humans. Tallying the increased CO_2 from industrial processes, the amount of fossil fuel extracted and combusted (Marland & Rotty 1984; Marland *et al.* 2006; Raupach *et al.* 2007), and the reduction of CO_2 sinks caused primarily by land clearing (Houghton 2003), indicates that humans have produced far more CO_2 than now remains in the atmosphere (Sabine *et al.* 2004a; Denman *et al.*, IPCC 2007, Ch 7; Canadell *et al.* 2007; Raupach *et al.* 2008). The total amount of carbon released from 1850 to 2007 that is attributed to these activities (Canadell *et al.* 2007) is enough to have raised the atmospheric concentration of CO_2 to nearly 500 ppm if all the carbon had remained as CO_2 in the atmosphere. Concentrations have not reached that level because the ocean and the terrestrial biosphere have the capacity to absorb some of the CO_2 (Sabine *et al.*, 2004b). Humans have produced CO_2 *faster* than the ocean and biosphere can absorb it; the remainder explains the observed increase in the atmosphere.

Natural causes of small, short-term variations in atmospheric CO_2

On short time frames ranging from seasons to a few years, natural causes have affected the modern atmospheric concentration of CO_2. Over a single year, northern hemisphere observing stations show significant, regular and cyclic variability of 5 to 7 ppm due to seasonal plant growth (Keeling *et al.*, 1976; Thoning *et al.*, 1989; Conway *et al.*, 1994); changes in the Southern hemisphere are less (Francey 2005). Over 3-5 year time periods, consequences arising from volcanoes and major ocean upwellings (notably ENSO) can cause interannual variability of about 4 ppm and 1 ppm, respectively (Bacastow 1976; Jones and Cox 2001; Jones *et al.*, 2001; Prentice *et al.*, 2001, IPCC 2001, Ch 3; Lintner 2002; Denman *et al.*, IPCC 2007). These changes are small, short-lived, and oscillatory compared to the large, long-trend rise of 107 ppm observed over the last 200 years.

An anthropogenic fingerprint: The decreasing ratio of ^{13}C to ^{12}C:

Human activities are also shown to be the cause of recent increases in atmospheric CO_2 concentrations by isotopic analysis of oceanic and atmospheric carbon dioxide. Since the last ice age, the pre-industrial age atmosphere has had a relatively constant ratio between two types of carbon, the isotopes ^{12}C and ^{13}C, varying slightly over a few millennia (Indermühle *et al.*, 1999). CO_2 produced from burning fossil fuels or land clearing, however, has a distinct isotopic fingerprint. Plants have a preference for lighter isotopes (^{12}C vs ^{13}C) when building their tissue (Park and Epstein 1960), resulting in a lower $^{13}C/^{12}C$ ratio than the atmosphere. Since fossil fuels are ultimately derived from ancient plants, fossil fuels also have low $^{13}C/^{12}C$. As CO_2 from these materials is released into, and mixes with, the atmosphere, the average $^{13}C/^{12}C$ ratio of the atmosphere decreases (Prentice *et al.*, IPCC 2001), as has been directly measured (Keeling et al 2005). This is consistent with the decreasing $^{13}C/^{12}C$ ratio measured from CO_2 trapped in ice cores for the period since 1850 (Francey 1999). Furthermore, $^{13}C/^{12}C$ analysis indicates that this ratio is also decreasing in the ocean. The atmosphere has an even lower $^{13}C/^{12}C$ ratio (fingerprint) than the ocean, indicating that ^{13}C-depleted carbon from fossil fuels and deforestation is passing from the atmosphere into the ocean (Quay *et al.*, 1992; Quay *et al.*, 2003).

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(The following references are a small part of the supporting body of evidence.)

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