Economics Legislation Committee
ANSWERS TO QUESTIONS ON NOTICE
Industry, Innovation and Science Portfolio
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DEPARTMENT: DEPARTMENT OF INDUSTRY, INNOVATION AND SCIENCE

TOPIC: Impact of global warming

REFERENCE: Question on Notice (Hansard, 20 October 2016, page 57)

QUESTION No.: SI-5

Senator ROBERTS: All right. That is two steps. The fourth step—or your third step—would be that warming is detrimental to the planet and to civilisation.
Dr Finkel: Exactly what the impact of global warming will be is determined—well, we have models to try to predict what that will be. And that is difficult. There are a lot of models, and it is not as easy to predict what will be the consequence of the warming as it is to say how fast a mass will move if you apply a certain force. But the models do predict significant climate change?
Senator ROBERTS: So you are relying on the models for that last part?
Dr Finkel: Absolutely.
Senator ROBERTS: Absolutely relying on the models. Would you be able—take it on notice—to provide me with a summary of the logic that you have just outlined and the empirical evidence at each stage, or, failing the empirical evidence, the models at each stage.
Dr Finkel: I could certainly give it a try on notice.
Senator ROBERTS: Thank you very much. I would appreciate that. It does not have to be long. I just want to check the logic and I just want to check the data sources.

ANSWER

Thank you for inviting me to respond to your question, "On what basis do you believe that carbon dioxide from human activities affects climate and needs to be curtailed?"

My written response here is consistent with my answer at the Senate Estimates Committee hearing on 20 October 2016.

To start, let me affirm, as you do, the importance of the scientific method. In particular, my confidence in scientific conclusions is particularly high when they are underpinned by 1) hypotheses based on principles of physics; and 2) evidence.

The answer to your question can be broken down into a series of sequential hypotheses and supporting evidence.

First, human activity contributes to rising atmospheric carbon dioxide levels.

The hypothesis is that carbon dioxide (CO_2) levels in the atmosphere have increased because emissions from burning fossil fuels have exceeded the rate of uptake by the oceans and vegetation. The validation of this hypothesis comes from the evidence that atmospheric CO_2 levels have risen, and supporting data confirming these elevated CO_2 levels have originated primarily from burning fossil fuels.

Confirmation of the hypothesis that CO_2 increases in the atmosphere have been driven mainly by fossil-fuel combustion comes from:

- measurements of the changing ratio of the isotopes Carbon 13 to Carbon 12 in the atmosphere and oceans (based on fossil-fuel CO_2 having a distinct ^{13}C:^{12}C ratio from CO_2 in the atmosphere and oceans);
- the observed dominance of the isotopic ratio changes in the northern hemisphere where most fossil-fuel emissions occur;
- a decrease in oxygen in the atmosphere mirroring the increase in CO_2; and
- analyses of historical emissions.

These multiple lines of evidence, taken together, confirm that the major source of elevated atmospheric CO_2 is from the burning of fossil fuels, rather than from natural sources.

Detailed accounting of emissions, natural sources and natural sinks of CO_2 indicate that of recent annual emissions totalling about 37 billion tonnes of CO_2, approximately 26% is absorbed by the oceans, 30% by vegetation and about 44% remains in the atmosphere.

The evidence of increasing atmospheric CO_2 levels is extensive. Ice-core air bubbles record atmospheric CO_2 levels prior to the Industrial Era. Direct atmospheric measurement over the last fifty years from multiple locations around the world, such as Mauna Loa in Hawaii and Cape Grim in Tasmania, clearly show a continual annual increase. The rate of increase is itself increasing year by year.

The atmospheric CO_2 concentration is now above 400 parts per million (ppm), up from approximately 280 ppm in the pre-industrial era. This is the highest concentration in 800,000 years, as shown by ice-core records. Last year the atmospheric CO_2 concentration at Cape Grim increased by 3.05 ppm, the most ever in one year.

Second, high concentrations of atmospheric CO_2 lead to warming of the oceans and atmosphere.

Consistent with fundamental principles of physics, the atmosphere is largely transparent to incoming radiation from the sun (visible light) but opaque to outgoing radiation re-radiated from the ground (infrared). This opacity arises from the absorption of infrared radiation by gases such as water, CO_2 and methane, resulting in a 'greenhouse effect' that elevates temperatures in Earth's atmosphere. The infrared-absorbing nature of CO_2 was experimentally confirmed by British scientist John Tyndall in the late 1850s. Swedish chemist Svante Arrhenius calculated the warming effect of CO_2 on climate in 1896.

The absorption and re-radiation of infrared energy within the atmosphere means that the average surface temperature is about 33 degrees Celsius warmer than it would be without the heat-trapping molecules. Without these greenhouse gases our planet would be a very cold place indeed.

The hypothesis is that anthropogenic emissions of CO_2 enhance the greenhouse effect by trapping more outgoing radiation, thus raising the temperature of the oceans and the atmosphere. As the temperature of the atmosphere rises, so too does its water-vapour holding capacity. This has the effect of amplifying the trapping of infrared radiation, thus warming the atmosphere further. This hypothesis is confirmed by observations of decadal changes in radiation above the atmosphere and at ground level. Extensive ground-based temperature measurements from thousands of monitoring stations over land and the oceans reveal the expected warming of the atmosphere. Other signals of a warming planet include the rising heat content of the oceans and the accelerated melting of ice sheets and glaciers.

Atmospheric and ocean surface temperature rises have been recorded by multiple, independent lines of evidence collected by institutions and agencies worldwide. These include the US agencies NASA and NOAA, the UK Met Office, and of course our own Australian scientists in universities, CRCs, and agencies such as CSIRO and the Bureau of Meteorology.

Warming of the Earth's lower atmosphere and oceans has continued decade-by-decade over the past fifty years. In that period, the average atmospheric temperature at the surface of the Earth has risen by approximately 0.6°C. The magnitude and spatial pattern of the observed warming cannot be explained by any alternative hypothesis, such as changes in solar output, internal variability, or volcanic activity.

Significant as that warming of the atmosphere is, the biggest changes have been in the oceans. Of the extra heat trapped by the added greenhouse gases, approximately 90% has accumulated in the oceans, owing to their high surface area, low reflectivity, and higher density and heat capacity relative to air. Measurements from multiple institutions, based on multiple methods and over long time periods, indicate that the heat content of the oceans has continued to rise in the last fifty years. The measured accumulated heat of the upper 700 metres of the oceans provides further confirmation of the energy imbalance calculated from the known rise in greenhouse gas concentrations in the atmosphere.

Further confirmation of the warming of the planet derives from observations of changing sea levels. Over the last century, global average sea level rose by about 1.7 mm per year. Between 1993 and 2010 this rate has increased to over 2.6 mm per year. The rise in sea level is attributed partly to the thermal expansion of seawater as it warms, and partly to the net melting of ice-sheets and glaciers.

Third, what is the climate impact of the warming atmosphere and oceans?

Understanding the climate changes that have and will result from the warming of the atmosphere and oceans is the extension of the science laid out in the first and second parts of this response. A range of reconstructions and projections emerge from increasingly sophisticated computer models used to construct possible future scenarios. These models reproduce observed historical climate trends when they include the effects of increased greenhouse gases in the atmosphere. They fail to reproduce the observed trends when they only include natural factors such as solar output, internal variability, and volcanic activity.

Increases in the incidence of some weather extremes, such as heat waves and the incidence of fire weather (meteorological conditions conducive to fires starting and spreading rapidly), are already discernible in Australia. The underlying warming trends that contribute to the probability of these extreme events are linked to the greenhouse gas increase in the atmosphere.

The question of whether or not CO_2 emissions from human activity need to be curtailed is a complex one. Our decisions about this question must be informed by the best available scientific insights, but they go beyond science into questions of politics and economics.

Information and Data Sources:

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