Main Source of Climate-Changing CO₂: A PowerPoint Narrative

FACT: A simple fact is a measurement of some physical quantity performed with the best available instruments, according to a precisely defined procedure, quoted with an associated uncertainty, and passed through a skeptical review, preferably one that repeats and verifies the measurement. A **compound fact** can be deduced from a number of simple facts (Helfand 2017).

A good example of a compound fact is the statement that the dominant component of the carbon dioxide (CO₂) currently being added to the atmosphere arises from the burning of fossil fuel (Helfand 2017).

1. **MAIN SOURCE OF CO₂ Compelling Evidence**

   Slides and notes from
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   Astronomer

   Adapted for PowerPoint
   Presentation
   By Larry Flammer

   **FINAL VERSION**

2. We have instruments that can count atoms and molecules, one by one. Here’s a table listing the numbers of each kind of particle in a sample of a million particles of air: Slide: **Composition of the Atmosphere** (ppm). These are facts. The "Greenhouse Gases" are shown in red.

   Has it changed?

3. **The Earth "Breathes" In and Out each Year**

   A 2% change between northern hemisphere spring and fall

   **Fact**

   3. **YES!** The Earth "Breathes" in and out each year (Fact). From a low point in October, CO₂ rises steadily to May, then falls until about September. Why is this? Well, when are plants most actively growing? Right! In the Spring-Summer. During that growing season, they take in more CO₂ (using the C for growing plant material), and release more oxygen (active photosynthesis). This reduces the amount of CO₂ in the atmosphere. In the Fall, active growing slows and stops. Bacteria break down the plant tissues, releasing lots of CO₂ which therefore increases in the atmosphere during Fall-Winter.

4. **Fact**

   4. [If anyone asks about the southern hemisphere, congratulate that person, and show map of the world. **Ask** "where is most of the plant-covered land mass?" They can clearly see that there is much more land mass in the northern temperate zone than in the southern temperate zone. So while the southern hemisphere does produce an offsetting effect, the northern hemisphere signal dominates the global average.]
5. Now show the Long Term Trend in CO\textsubscript{2} over 44 years (1958-2002) - Mauna Loa Monthly Mean CO\textsubscript{2}.

Ask: "How can we know where this additional CO\textsubscript{2} is coming from?

Advance to next slide, same as previous, but with extrapolation of the curve, climbing ever higher, steeper.

6. Same slide as previous, but with extrapolation of the curve to 2017, climbing ever higher, steeper.

7. Show slide of Measured Rate of O\textsubscript{2} Decline: 19 ppm per year. {Also, the seasonal fluctuations of O\textsubscript{2} are perfectly out of phase with the CO\textsubscript{2}.} Ask "Where is the O\textsubscript{2} going? Remember what's happening to the CO\textsubscript{2}? It's increasing! Could the O\textsubscript{2} be going into the new CO\textsubscript{2}?

FACT: The mass of missing O\textsubscript{2} is about the same as the O\textsubscript{2} mass in new CO\textsubscript{2}. If CO\textsubscript{2} comes from the "combustion" (combining with O\textsubscript{2}), of carbon-containing materials: C + O\textsubscript{2} = CO\textsubscript{2}, this is what we would expect. [Called "cellular respiration," the way most living organisms extract energy from food.]

8. Something new we need to look at here: Atoms of each element exist in different forms - called isotopes - each with the same number of protons (and therefore, chemically identical), but with different numbers of neutrons, so they have slightly different weights). Carbon comes in three isotopes [See slide]: Most of the carbon in our environment (about 99%) is C-12, with only about 1% C-13 plus a tiny amount of C-14. They're all chemically carbon, but the heavier isotopes move more slowly, and therefore are less likely to react chemically. That's why plants have less C-13 and C-14 than the air around them – they discriminate against the slow-moving, heavier isotopes in the process of photosynthesis.

[By the way, C-14 is radioactive, and slowly converts to N-14, with half the C-14 content converting to N-14 every 5,730 years, so that's why C-14 dating can be done on organic materials (dead bones, trees, or objects made from them), so we can tell when they died, but only back in time about 50,000 years].
9. "It's possible to measure the precise amount of each isotope in a given sample, and the most useful data points for comparison are the proportions (ratios) of C-13 to C-12, or C-14 to C-12. These measurements have been taken directly in our atmosphere for the past 40 years, and from tree rings and sediment cores going back many centuries."

SHOW GRAPH of Changes Began ~1800 and Are Accelerating. These data show a gradual decline in the C-13/C-12 beginning around 1800, when the industrial revolution began. Over the past 30 years, this has accelerated downward rapidly.

10. The C-14/C-12 ratio has also been declining rapidly over the past 30 years.

SEE SLIDE of Clean Air Measurements at Niwot Ridge, CO: Note the predicted decay rate of C-14 (in red) vs the clear downward trend in a recent 6 year period (2003 - 2009).

11. SLIDE: Ask "What does all this say about the source of the rapidly rising CO2 content of Earth's atmosphere?"

12. Show slides of various sources of CO2 that could be contributing to the atmospheric concentration along with the C-13/C-12 ratio from each:

- volcanoes (high C-13/C-12 ratio compared to the air),
- ocean-air exchange (medium – by definition, consistent with the air),
- C as CO2 from living plants (low, for reasons noted above).
13. Various ratios of $^{14}$C/$^{12}$C in CO$_2$:

- Nuclear bomb tests in the atmosphere (high),
- Living plants exchanging on an annual basis (medium),
- Long-dead plants we call "fossil fuels": coal, oil and natural gas (low).

14. **SLIDE: Amount - Sources - New CO$_2$ in the air.**

**NOTE:** Both the C-13 ratio and the C-14 ratio are declining.

These declining ratios rule out volcanoes and ocean-atmosphere exchange, since both in nature have higher C-13/C-12 ratios. The falling C-13 values mean plants must be involved.

The plunging C-14 values mean we must be adding CO$_2$ to the air that is highly deficient in C-14 and that can’t come from modern plants whose C-14 was enriched by the bomb tests in the 1950s.

Therefore, the growing CO$_2$ levels must come from long-dead plants in which the C-14 has all decayed away (into N-14).

Thus, the dominant fraction of the new CO$_2$ in the atmosphere must come from burning fossil fuels.

15. **FACT**

Earth’s atmospheric CO$_2$ content is increasing at 1% per year and nearly all of it is a consequence of burning fossil fuels.

Most of the slides were provided by Dr. David J. Helfand. **Narrative** adapted (with kind permission of the author) from the article in the May/June 2017 issue of the *Skeptical Inquirer*: "Surviving the Misinformation Age" by Dr. David J. Helfand, Chair of the Department of Astronomy at Columbia University and a CSI Fellow, as well as past-president of the American Astronomical Society. His recent book, *A Survival Guide to the Misinformation Age*, enumerates the scientific habits of mind needed for countering the “alternative facts” and misinformation so prevalent today.