

Global Warming Theories Confirmed

By Richard W. Franke

This is the latest installment in our *Signs of Sustainability* series, organized by *Sustainable Tompkins*. Visit them online at www.sustainabletompkins.org.

"Is the Earth's climate changing? The answer is unequivocally 'Yes.'" So wrote the Intergovernmental Panel on Climate Change (IPCC) in its 2001 Third Assessment Report. The report reflected an overwhelming scientific consensus that global warming was occurring and that human activities—in particular the release of greenhouse gases such as carbon dioxide (CO₂), methane and nitrous oxide into the atmosphere—were a major cause. The Fourth and Fifth Assessment reports have confirmed and elaborated on the 2001 document.

The IPCC's 2001 confirmation of human-induced global warming resulted from 142 years of scientific

research. In 1859, the Irish physicist John Tyndall had discovered the "greenhouse effect" in which CO₂ reflects certain wavelengths of solar heat back to Earth. In 1895, the Swedish chemist Svante Arrhenius noted that the smoke from industrial factories was likely to eventually warm the planet.

For the first half of the 20th century, most geologists and other scientists focused on explaining the onset and decline of ice ages. But in 1960, the American chemist Charles Keeling announced measurements showing that CO₂ in the atmosphere was increasing at a rate much faster than had been thought. This brought back interest in what Arrhenius had said at the beginning of the century about smoke from industrial stacks eventually warming the Earth. Over the next 41 years, intense and elaborate scientific undertakings unfolded to test the possibility that human

activities were changing the atmosphere and thus the planet's climate. Scientists made use of the technologies coming out of labs and workshops around the world. Weather balloons, rockets and satellites made it possible to accumulate vast new tables of measurements across increasingly large stretches of the atmosphere. Computers, primitive and clunky at first, became faster and smaller and made possible calculations that would not have been feasible without their digital circuits.

Mathematicians discovered chaos theory, which indirectly helped establish the possibility that small changes in some element of Earth's climate could bring about large effects—sometimes called the butterfly effect, referring to the idea that a butterfly flapping its wings in one area could cause movements that turn into a tornado several hundred miles away. Nuclear testing, in what might be its only positive contribution to the world, left behind isotopes that provided scientists with tracer atoms to determine how the oceans absorb heat.

Through it all, Keeling's measurements of the steady march of

CO₂ levels provided an anchor that kept the focus on greenhouse gases.

Ice cores drilled in Greenland, Antarctica and in some glaciers provided a significant source of data. The drill at Vostok in Antarctica went down 3,623 meters (11,886 feet), revealing some 400,000 years of climate history. The Vostok ice cores and others helped establish the close connection between CO₂ levels and average world temperatures.

Scientists learned that forest cover might play a significant role in regulating greenhouse emissions—a discovery of great importance today. They also learned about the massive movements of water in the giant ocean circulations and came by accident on the danger of the ozone hole and its connection to chlorofluorocarbons (CFCs) used as propellants in some spray-can products.

Another key was the development of climate modeling. After a slow start resulting from primitive technology and limited data, by the 1980s, modelers with better data nearly captured the climate in a set of mathematical equations. This led to predictions, starting in the 1990s, of the likely temperature effects of particular parts per million of CO₂.

Richard W. Franke writes about the history of sustainability. He is professor emeritus of anthropology at Montclair State University, a resident of Ecovillage at Ithaca and a board member of Sustainable Tompkins.