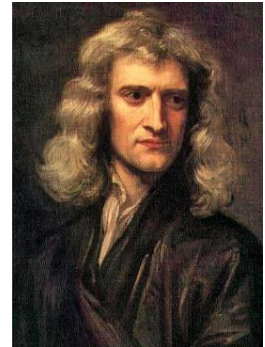


Are we Trapped by our Own Successes?

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This is an account of events that have led to the climate crisis, and the possibility that it could lead to the extinction of all life on earth. How is it that climate scientists discuss such an outcome of advancements in technology and the comforts associated with them? This is about the consequences of the use of coal, oil and gas for fuel. These fuels drive heat engines that provide motive power and generation of electricity to run our civilization, all of which have thus far been to the benefit of humankind.

The story can be traced thousands of years into antiquity, but from my background in leading a large, interdisciplinary course called "Ecology, Technology and Society," and the understanding of the history of science that came with it, the place I start is with Sir Isaac Newton (1642-1727). In the **1660's** he discovered three laws of motion plus the law of gravitation, which required action at a distance, a concept that scientists of his day reacted to in horror. Yet, without that strange action at a distance, we would have no way to explain the motion of planets. The main law is



$$\text{Force} = \text{Mass} \times \text{Acceleration}$$

This is a differential equation that must be integrated twice to find position. Newton was an English mathematician, physicist, astronomer, theologian and author. Before him no method of integration existed, so he had to develop a method, which was called calculus. Newton's method was complex and difficult to use, but almost simultaneously the German Gottfried Wilhelm Leibniz (1646-1716), polymath, logician, mathematician and natural philosopher developed his version of calculus, which uses the notation standard today. British mathematicians were slow to adopt Leibniz's method and thus set back the development of science in Britain by a century. With the laws introduced by Newton and the mathematical tool developed by Leibniz, during the 18th century many mathematical scientists and engineers contributed to the development of the engineering sciences taught in engineering schools today and form the backbone of the steadily expanding INDUSTRIAL REVOLUTION.



Thomas Newcomen (1664-1729), an English inventor, invented the steam engine in **1712**, with steam being generated by burning coal. Joseph Black (1728-1799), a Scottish physicist and chemist discovered **carbon dioxide**, CO₂, in **1754**.

James Watt (1736-1819), a Scottish inventor, mechanical engineer and chemist in **1776** made fundamental improvements on the steam engine, enough to be able to mount an engine on a moving vehicle or boat.



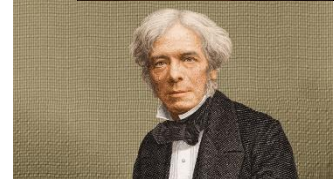
Robert Fulton (1765-1815), an American inventor and engineer, invented and in **1807** operated the first commercially successful steamboat, powered by coal.



John Blenkinsop (1783-1831), an English mining engineer, in **1811** invented the first steam locomotive with its coal cars trailing behind.



Michael Faraday (1791-1867) a British physicist and chemist is best known for his discoveries in the **1820's** of electromagnetic induction and electrolysis. His biggest breakthrough was his invention of the electric motor and, running it backwards, the electric generator, which is the basis for commercial generation of electricity, without which our lives would be primitive. The generator was driven by a steam turbine with the steam produced by burning coal.



Up to a few years ago the 1000-megawatt power generator in Becker, Minnesota, required four one-mile-long train loads of coal from Montana every day. Around the world, there are today the equivalent of 700 of such facilities, all releasing CO₂. Natural gas is now used, which would be equivalent to half as much coal every day.

Joseph Fourier (1768-1830), a famous French mathematician, in **1824** found that certain gases allow sunlight to pass unimpeded but absorb heat radiation.



John Tyndall (1820-1893), an Irish natural philosopher of renown, did experiments and speculated on how fluctuations in water vapor and carbon dioxide could relate to climate change.



1859 Petroleum: Pennsylvania, Canada, Azerbaijan and Romania all started oil production close to this date. Petroleum and coal had been known and burned for thousands of years, but it took the inventions of the steam engine, the electricity generator and the internal-combustion engine to vastly increase the need for these fuels.

The Internal-Combustion Engine enormously expanded the use of refined oil. In the 19th Century many engineers contributed to its development. In **1886** German engineer Karl Benz (1844-1929) began the first commercial production of vehicles using ICEs. The ICE powered vehicle replaced the horse and led to freedom of the road. It became so popular that there are now more than 1.2 billion of them worldwide, a number growing quickly, almost all releasing CO₂ into the air. Only about 0.2% as many electric cars are in operation.

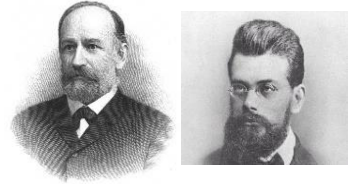


Adolfo Bartoli (1851-1896), an Italian physicist, discovered radiation pressure. James Clerk Maxwell (1831-1879), a Scottish mathematical physicist in the **1860's** formulated the equations of the electromagnetic field and found that radiation pressure followed from his equations, thus it is

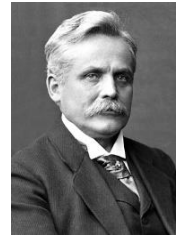


called Maxwell-Bartoli pressure. Understanding of radiation pressure is necessary to understand the energy balance that determines the earth's temperature.

Josef Stefan (1835-1893) and his student Ludwig Boltzmann (1844-1906), both Austrian physicists, discovered in **1884** the Stefan-Boltzmann law that states quantitatively that the magnitude of the radiance from a Black Body is proportional to the fourth power of the absolute temperature of the body's surface. This law is essential in calculating the temperature of the Earth's surface needed to balance the energy input from the Sun.



Wilhelm Wein (1864-1928), German physicist, in **1893** discovered the Wein Law of Black-Body radiation, which states that $\lambda_{max}T = const$, where λ_{max} is the maximum wave length in a statistical distribution and T is absolute temperature. This law showed that the maximum wavelength of radiation pressure from the surface of the earth lies in the range of wave lengths absorbed by CO₂, water vapor, methane and nitrous oxide.



Svante Arrhenius (1859-1927), was a Swedish scientist and student of Boltzmann. In developing a theory to explain the ice ages, Arrhenius, in **1896** was the first to use basic principles of physical chemistry to calculate the extent to which increases in atmospheric CO₂ will increase Earth's surface temperature through the greenhouse effect. He thought that increases in CO₂ might be beneficial, but now it was known why increasing CO₂ will increase the temperature of the earth's atmosphere and why the lack of trace gases in the earth's atmosphere will result in a temperature too low to support life.

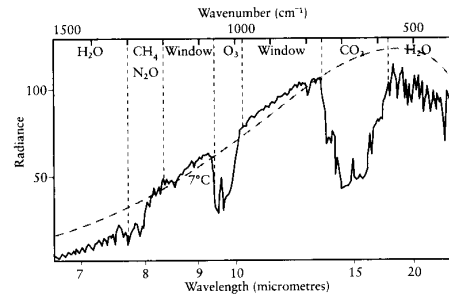


Currently there are about 408.5 parts per million of CO₂, in our atmosphere. This is only 0.041%. Climate deniers argue that such a small percentage can't have any effect, but without it the earth's surface temperature would be too low to support life.

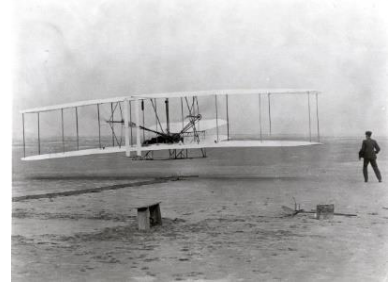
Nitrogen, N₂, and Oxygen, O₂, are 2-atom molecules. They have no vibration modes in the infrared region of the spectrum. These molecules make up more than 99.9% of the atmosphere and do not absorb radiance from the earth.

Carbon Dioxide, CO₂, Water, H₂O, Nitrous Oxide, N₂O, and Ozone, O₃, are 3-atom molecules and from experiments have vibration modes in the infrared region of the spectrum. They absorb and reradiate energy radiated from the earth. For thousands of years the amount of these gases in our atmosphere has been neither too great or too small, thus permitting a healthy atmosphere for humankind – neither too hot nor too cold. Now we are thoughtlessly increasing them!

This chart, taken from Peter Wadham's book¹, shows Radiance vs. Wavelength as measured by a satellite travelling over the Mediterranean Sea. The distribution is close to Wein's statistical distribution for 7°C. The absorption band for CO₂ is by far the largest and is near the maximum wavelength, which is why CO₂ is the most important greenhouse gas.



Flight: In December **1903**, the Wright Brothers are shown here experiencing the first sustained flight of a heavier-than-air aircraft. Because it was believed that aircraft would be useful in war, in 1915 the United States Congress established the National Advisory Committee for Aeronautics (NACA) to study problems of flight. In the late 1950s NACA was recommissioned as NASA. In World War I and then World War II, the art of flight advanced rapidly. Today there are about 39,000 aircraft in existence carrying about 4.1 billion passengers per year. They are all fueled by a highly refined version of a CO₂-releasing fuel. Stopping of flight now to reduce CO₂ is unthinkable. It would stop civilization in its tracks! We are locked in!



From page 36 of *The Global 2000 Report to the President*, published in 1982:

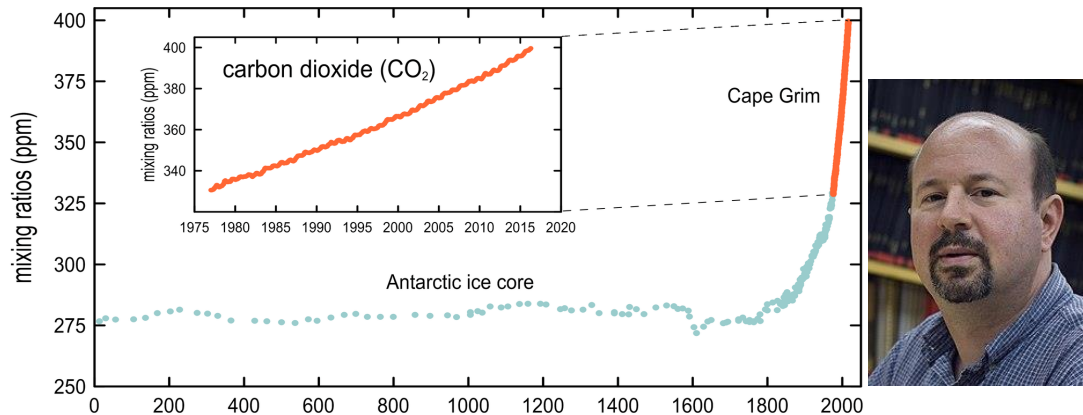
“Another environmental problem related to the combustion of fossil fuel is the increasing concentration of carbon dioxide in the earth’s atmosphere. Rising CO₂ concentrations are of concern because of their potential for causing a warming of the earth... The CO₂ content of the world’s atmosphere has increased about 15 percent in the last century and by 2000 is expected to be nearly a third higher than preindustrial levels. If the projected rates of increase in fossil fuel combustion (about 2 percent per year) were to continue, a doubling of CO₂ content of the atmosphere could be expected by the middle of the next century; and if deforestation substantially reduces tropical forests (as projected), a doubling of atmospheric CO₂ could occur sooner. The result could be significant alterations of precipitation patterns around the world, and a 2°-3° C rise in temperatures in the middle latitudes of the earth... Even a 1°C increase in average global temperature would make the earth’s climate warmer than it has been any time in the last 1,000 years.”

In **1988**, climate scientist James E. Hansen, from 1981 to 2013 Director of the NASA Goddard Institute for Space Studies in New York City, testified before Congress on the urgent necessity to contain the increasing level of CO₂ in the atmosphere. He headed a group that had the



¹ Peter Wadhams, *A Farewell to Ice*, Figure 5.1

scientific talent and tools needed to study the subject exhaustively. He has been and continues to lecture widely on this topic and its importance for humankind.²



This chart shows CO₂ in parts per million (ppm) vs. time in years, showing the “hockey stick” behavior introduced by climate scientist Michael Mann. It was strongly criticized by climate deniers but has been confirmed by many scientists. It shows how much the growing Industrial Revolution, beginning with the steam engine, contributes through burning of coal, oil and natural gas to the increase of CO₂ in the atmosphere. Since 1957 the level of CO₂ has been measured daily at 11,000 ft at the Mauna Loa Observatory in the Island of Hawaii.

The current level (2019) is 408.5 ppm and is rising at a rate of 2.4 ppm per year.

In **2006**, former Vice President Al Gore published his book *An Inconvenient Truth: The Planetary Emergency of Global Warming and What we can do about It*. He said, “I vowed to make the climate crisis the top priority of my professional life.” While not a scientist himself, he spent a great deal of time talking with climate scientists, which becomes clear from reading his book. If we had taken him seriously in 2006, the earth would be much better off and perhaps we could have averted the most serious consequences of the climate crisis. We wonder now if it is too late. Al Gore still lectures on the climate – urging action.



Dr. Peter Wadhams, Emeritus Professor of Ocean Physics in the Department of Applied Mathematics and Theoretical Physics at Cambridge University, authored the **2017** book *A Farewell to Ice*. In Chapter 14: “A Call to Arms” he says “*The discovery in 2015 of very high long-term sensitivity of the planet to greenhouse gases³ is of utmost importance in clarifying what should be our*



² https://www.ted.com/talks/james_hansen_why_i_must_speak_out_about_climate_change

Please listen to Dr. Hansen’s TED talk to understand much better why we must act.

³ Waddell, David (2015), *Facing the Harsh Realities of Now*. www.apollo-gaia.org.

priority as human beings in the crisis that faces us. It shows that the existing level of carbon dioxide in the atmosphere is enough to cause unacceptable amounts of warming in the future. We no longer have a 'carbon budget' that we can burn through before feeling worried that we have caused massive climate change. We have burned through the budget and are causing the change now.

We have destroyed our planet's life support system by mindless development and misuse of technology. A mindful development of technology, first for geoengineering⁴, then for carbon removal, is now necessary to save us. **This is the most serious and important activity in which the human race can now be involved, and it must begin immediately.**"

Dr. David Wasdell, Director of the ten-year Apollo-Gaia study, mentioned in the footnote on page 5, concluded: "*Detailed analysis of historical planetary response to change in concentration of carbon dioxide reveals an eight-fold amplification of CO₂ forcing in contrast to the three-fold amplification predicted by the IPCC climate modeling computer ensemble. Applying the corrected value of Climate Sensitivity multiplies the previously predicted temperature rise by more than 2½ times in response to any given change in CO₂ concentration.*"



The IPCC's prediction that the earth's mean temperature must be held to a rise of no more than 1½°C means that an IPCC predicted rise of 1½°C would really be 1.5×2.5 = 3.75°C, whereas the IPCC has estimated that a rise of only 2°C will be catastrophic.

The Earth's mean temperature is rising at an increasing rate. I can point to three events that in 2019 are much different than in 2018:

1. A nephew of mine runs a farm near Pocahtontas, Iowa. He told me that this year was close to catastrophic because there was so much rain.
2. I have a friend whose family owns a farm 35 miles north of Detroit. He told me that his tenants and other farmers were unable to plant their corn and soybeans this year because fields were too wet during the entire planting season.
3. The weathermen say that the rain in the USA this year has set a record.

Compared with the summer of 2018, these events stand out. Warmer air holds more water. Because, as shown in the chart on the next page, the Northern Hemisphere Ocean temperature is rising at an increasing rate, we can expect the changes and effects from this year to next year will be greater than they were from last year to this year; but it is still very slow, only about 0.4°C per decade, yet the changes from last year to this were very noticeable.

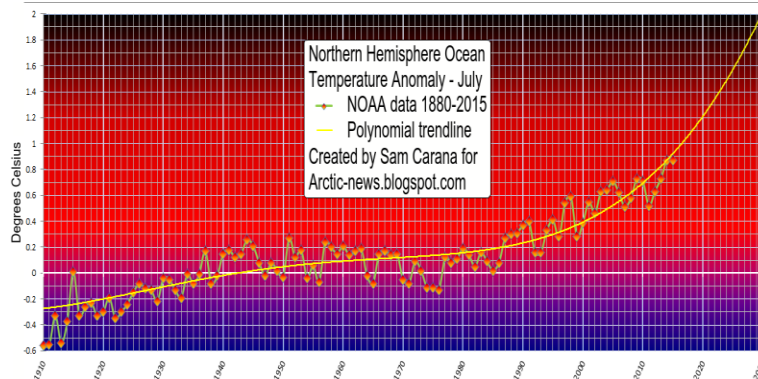
⁴ Wadhams criticized geoengineering but said that we have no choice.

Concern about the climate is increasing rapidly. Thanks to Greta Thunberg hundreds of thousands of young people have staged demonstrations, the biggest on March 15, 2019 and more this fall.



The organization *Extinction Rebellion* started in London about a year ago. There are now chapters in many countries and teams of them often lay down in busy streets to call attention to the need for serious action. An organization called *A Climate Mobilization* has formed, declaring that the Climate Emergency requires a World War II level of commitment starting immediately. And there are many others. We can't turn on the radio without hearing the latest about the climate.

Yet, where is our general public? Ford Motor Company has decided to manufacture only F-150 pickup trucks because so few people want the much lighter-weight sedans. General Motors has decided to close a plant that has made their smallest sedan because the public they see only want larger and hence heavier vehicles, which will release more CO₂.



For the earth's mean temperature to remain steady, the energy absorbed from the sun must match the energy radiated away into space. Eight hundred thousand years of ice-core data have shown how the earth's mean temperature has risen and fallen in step with the amount of carbon dioxide (CO₂) in the air.⁵ Beginning over 200 years ago, due to burning of coal and then oil, the amount of CO₂ in our atmosphere has risen, slowly at first and then more and more rapidly each year. It is now almost 50% higher than the maximum during the previous 800,000 years and rising rapidly.

Established science⁶ has shown that CO₂ is the main absorber of energy that is radiated away from the earth's surface, which means that with more CO₂ in the atmosphere, less energy is available to be radiated into space from the top of the atmosphere. To restore

⁵ In his TED talk, Dr. James Hanson has explained why the temperature often leads the change in CO₂.

⁶ Dr. Peter Wadhams, *A Farewell to Ice*, Chapter 5, "The Greenhouse Effect."

balance between incoming solar energy and energy radiated away, the surface temperature of the earth must increase, but it takes time to restore balance – at least a decade.

Moreover, the solar energy absorbed by the earth is increasing because ice cover in the Arctic is decreasing and decreasing more rapidly every year,⁷ which means that more solar energy is being absorbed by the arctic ocean rather than reflected into space. This additional energy heats the atmosphere even more. As the CO₂ content of our atmosphere continues to rise, our atmospheric temperature slowly continues to rise. Because it takes time for these changes to take place, today's temperature is lower than the level it will reach, which continues to rise as the CO₂ content continues to rise. At some point, human intervention will no longer be able to control further temperature increases and life on earth will gradually become more difficult.

To keep the earth's atmospheric temperature from rising dangerously, we must stop burning fossil fuels and we must remove CO₂ from the atmosphere. This is a very expensive proposition and requires cooperation of every nation on earth. Solar energy that reaches the earth can be reduced by placing reflecting particles in the atmosphere, although some climate scientists explain why that is a bad idea. Our lives are at stake and every method to reduce the atmospheric temperature must be considered. The situation must be treated the way we acted after December 7, 1941.

Serious action must be taken now, when the temperature is still tolerable. If we wait too long, the earth's atmospheric temperature will no longer be subject to human control, if it is now. Most people are not trained in the sciences, and when faced with a totally new situation will find it difficult to believe anything that is not directly in front of them. Many will not act on what climate scientists have warned will happen until it happens. And it is likely that many of us are too busy with current activities to think about an unprecedented problem. Moreover, many people depend on the fossil-fuel industry for their livelihood and will fight and have fought every thought of reducing CO₂. Ghosts of Edward Bernays, nephew of Sigmund Freud, the climate deniers still influence people's thoughts and actions.

Highly efficient electrified transportation with electricity obtained from a non-polluting source and designed to be able to attract many riders is essential.

For the latest information on climate, see www.arctic-news.blogspot.com

Are we trapped by our successes? What is the way out?

⁷ National Snow and Ice Data Center, Boulder, Colorado.

