American Journal of
Biomedical Science & Research

www.biomedgrid.com
ISSN: 2642-1747

Review Article

Climate and the Future

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To Cite This Article: *Ola M Johannessen*. Climate and the Future. Am J Biomed Sci & Res. 2025 26(3) AJBSR.MS.ID.003441,*
DOI: 10.34297/AJBSR.2025.26.003441

Received: March 21, 2025; **Published:** March 25, 2025

Summary

This is a brief reflection on climate development since 1896 and up to 2100 based on history, greenhouse gases emissions, global warming, the Paris Agreement, the future and population growth. It is very uncertain whether the Paris Agreement which requires that the global air temperature be kept below 2 degrees Celsius, will be achieved due to insufficient reduction in greenhouse gases, of which CO_2 is the most important, and furthermore limiting population growth up to 2100 which is responsible for the emissions.

History

Dry air that we breath today contains about 78% nitrogen, 21% oxygen, 1% argon but only 0.04 % carbon dioxide, CO_2, (or 400 parts per million, abbreviated to ppm) and 0.0002 % methane. *Svante Arrhenius* from Sweden, Nobel Prize in Chemistry 1903, published as early as 1896 the importance of carbon dioxide as a greenhouse gas in the atmosphere. He also projected that if the concentration in the atmosphere increased by 2,5 to 3 times from pre-industrial times, the temperature in the Arctic would increase by 8 to 9 degrees Celsius, which is of the same order of magnitude as the global climate models project today.

Greenhouse Gasses

Carbon dioxide has a lifetime in the atmosphere of more than 100 years. Even if we could stop all emissions of CO_2 today, it would take hundreds of years before the temperature in the atmosphere would decrease. Therefore, the world must prepare for a warmer climate in the future with the consequences it has for the world's population and nature. Water vapor in the atmosphere is the most important greenhouse gas and contributes about 50%, clouds with 25% and carbon dioxide with about 20%. But unlike carbon dioxide, water vapor does not contribute to climate change itself but follows changes due to other reasons such as increasing temperature in the atmosphere due to increasing CO_2 and natural variations in climate which are very important. Without greenhouse gases in the atmosphere, the global average temperature would be about minus 18 degrees Celsius while today it is about 15 degrees Celsius.

Global Warming

We can wonder why CO_2, which only had a very small concentration of 0.0285% in the atmosphere before the industrial revolution around 1900, which today in February 2025 has increased to 0.0427% (gml.noaa.gov) can have so much influence on the global climate changes that we observe today with increasing global temperature, heat waves in the atmosphere and in the oceans, rising sea levels, melting of the polar ice caps, glaciers and the Greenland and Antarctic land ice with major consequences for humans, animal species, nature and economy. As mentioned before, *Svante Arrhenius* indicated this effect of CO_2 as early as 1896, but this was first quantified by *S. Manabe* in a paper in 1975 where he and his co-author *R. Wetherald* with one of the first global climate models showed that by doubling CO_2 in the atmosphere since the industrial revolution, from 0.03% to 0.06% the global temperature would increase by 2.3 to 2.9 degrees Celsius. This result corresponds well with the more complex global climate models used today which

indicate an increasing global temperature of 2.5 to 4 degree Celsius by 2100. Furthermore, *Hasselman «fingerprint paper»* in 1976, which laid the foundation for the climate change we observe is man-made. Both *Manabe* and *K. Hasselmann* received the "Nobel Prize for Physics" in 2021 for their major contributions to man-made climate change.

Paris Agreement

Based on a long series of climate-related papers, the "Intergovernmental Panel on Climate Change (IPCC)" was formed in 1988 by the UN agencies the World Meteorological Organization (WMO) and the UN Environment Programme (UNEP). This panel is today, as we all know, the world's leading authority on current and future climate change with regular publications of important reports that formed the background for the Paris Agreement, which was approved on 12 December 2015 at the UN Climate Change Conference in Paris. The agreement focused on reducing greenhouse gases in the atmosphere by keeping the global temperature below 2 degree C and preferably limiting it to 1.5 degree C compared to pre-industrial levels. By 2023, 195 countries plus the EU had signed it. If the global temperature is to be kept below 2 degree C, the CO_2 concentration in the atmosphere must not be higher than 0.045% or 450ppm, by 2060 and reduced to 0.0425% or 425ppm, by 2100 (IPCC,2021, tableSPM.1, Summary for Policymakers, «IPCC.ch»). It can be mentioned that the total emissions of CO_2 to the atmosphere today are about 40 billion tons or 40 Gigatonnes per year of which about 25% is absorbed by the ocean and about 25% by vegetation such as forests, marshes and other vegetation, fortunately for the World Community. It can be mentioned that it took 79 years from *Arrhenius* 1896 publication to *Manabe* and *Hasselmann* 1975 and 1976 publications showing that CO_2 increase in the atmosphere was the cause of increasing global temperature and a further 40 years after this before the Paris Agreement in 2015 was approved, a very long period,119 years, before politicians and the World Community approved this and understood the seriousness of the ongoing climate change.

The Future

The CO_2 concentration in the atmosphere in February 2025 is 0.0427% or 427ppm, and the annual increase since 2010 has been about 2.4ppm/year (*gml.noaa.gov*). If this increase continues, CO_2 will increase to more than 500ppm by 2060, far above the 450ppm which is the Paris target in 2060. If the world community is to reach the Paris target in 2060, we only have about 25ppm left over a period of 35 years, that is about 0.71ppm per year, which requires a cut of about 1,7ppm/year or about 70%, a grand challence for the World Community, proably not achivevbel?

Population Growth

Another way to look at this is to also to examine the impact of population growth on climate change. I have calculated the correlation between the CO_2 concentration and the population over 6decades,1963-2019, see (Figure 1), which show that this correlation is perfect indicating that the CO_2 concentration in the atmosphere is man made. Therefore, it is important to break this relationship since the world's population is projected to increase in the future to 10billion in 2100. Therefore, it is also important to limit this population growth including less personal consumption for all of us, at least in the the wealthy countries in the world.

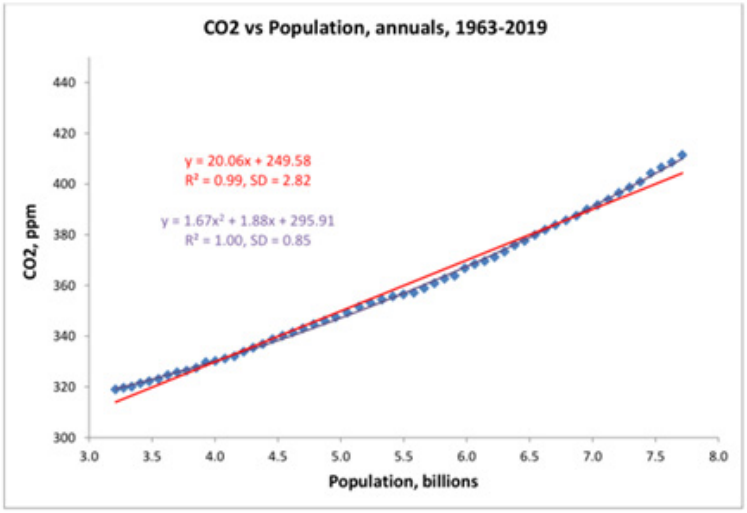

Figure 1

Conflict of Interest

None.

Acknowledgement

None.