

# Characteristics of climate change in the years 1850-2100

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## Abstract

This article analyzes the basic factors influencing climate warming, as well as features characterizing the current picture of this phenomenon and presents possible directions of its development in the years 2022-2100. At the same time, it indicates that there is a possibility to stop the current trend of unfavorable changes and transform the climate into a more friendly phenomenon for people and their planet. First of all, anthropogenic CO<sub>2</sub> emissions should be brought below net zero, and emissions of other greenhouse gases should be reduced as much as possible. This requires focusing on the development of a low-emission economy as well as circular economy and RES, as well as continuous improvement of the natural environment and a rational end to the war between Russia and Ukraine and the creation of sensible conditions for common security in the "global village".

**Keywords:** climate change, greenhouse effect, "ozon hole", circular net zero CO<sub>2</sub> emissions, greenhouse gases, Putin's fuel crisis

## 1 Introduction

Initiated in the first half of the 19th century (in England in the second half of the 18th century) the entirety of technical, economic and social changes related to the emergence of a large factory industry gave rise to the modern industrial civilization. It was based primarily on various technical inventions, which significantly influenced the increase in the effectiveness of human activity, mainly by expanding its production capacity. The nascent modern industrial civilization, as part of its dynamic development, began to cover more and more geographical areas, as well as directions of activity, while maintaining care for improving its perfection.

This development, constantly enriched with new inventions, innovations, as well as modern technologies and modern infrastructure, generated many different benefits for individual countries and people. Unfortunately, human activities that led to these beneficial transformations were not always neutral for the natural environment. Today, it is rather obvious to everyone that the current climate warming is primarily caused by mankind, or rather by their not very rational activity. The current effects of climate change sometimes inspire fear and horror and are the source of tragedy and misfortune for many human communities. At the same time, they increase fears about the future, and at the same time they are the basis for formulating conclusions and determining actions that should be taken immediately to prevent a catastrophe.

The aim of the article is to present the conditions of climate warming and to indicate the actions that are necessary to prevent the assumed negative scenarios of these changes from being confirmed at the end of this century.

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## 2 Characteristics of the modern climate

The analysis of the results of climate monitoring carried out for over 170 years allows us to conclude that the culprit of the changes taking place in it is primarily human, or rather human activity. The current recorded magnitude of these changes is arguably the largest since humankind has inhabited our planet. The scope and scale of these changes is also related to their pace, as never before have they occurred so quickly and in such a short time. Also, never before has any of the climate changes threatened almost 8 billion human population, which at the beginning of the 20th century was 5 times smaller, and in the middle of the 18th century 10 times smaller (only 750 million).

In the same period of time (i.e. since 1750), humans are also indisputably responsible for the increase in the concentration of greenhouse gases. This increase was constant, and its height was dynamically increasing. Reaching in 2021 average annual (from 2010) 418 ppm (parts per million air particles) for carbon dioxide (CO<sub>2</sub>) and 1876 ppb (parts per billion air particles) for methane (CH<sub>4</sub>) and 336 ppb for nitrous oxide (N<sub>2</sub>O). Concentration increase since 2010 for CO<sub>2</sub> it was 20 ppm, for CH<sub>4</sub> - 68 ppb and 10 ppb for N<sub>2</sub>O. At this point of consideration, it should be noted that in the analyzed period (last 170 years), land and oceans absorbed 59% of the total CO<sub>2</sub> emissions.

Human activity also contributes to the warming recorded for many years. In 2011-2020, the temperature was 1.09°C higher than in the period 1850-1900, with an increase in temperature over land of 1.59°C and over oceans of 0.88°C, clearly indicating the ongoing warming of the climate. It also confirms that the main perpetrators of these changes are humans, who by far carry out the largest part of their activity on land, although its effects also partially extend to the oceans. An example of its disproportion is undoubtedly the increase in temperature, which in the compared period was almost twice as high over land as over oceans.

It is estimated that in the analyzed period, well-mixed greenhouse gases (CO<sub>2</sub> - carbon dioxide; CH<sub>4</sub> - methane; N<sub>2</sub>O - nitrous oxide; freon, which is responsible for about 20% of greenhouse gas emissions; ozone, which generates disturbances in the low layers of the atmosphere) contributed the warming from 1.4°C to 1.9°C, while the cooling from 0.4°C to 0.8°C was contributed by other anthropogenic factors, in particular aerosols. In turn, under the influence of natural factors, the Earth's air temperature has changed from -0.1°C to 0.1°C, while internal climate variability is expressed by an increase from -0.2°C to 0.2°C.

Ozone is of great importance for man and the functioning of our planet, which, despite the fact that it constitutes 5/100,000 of the mass of the atmosphere, the coating of this gas actually protects life on Earth. However, as a result of irrational and thoughtless human activity, this coating began to disappear noticeably. The process of this disappearance was first noticed by NASA in 1974, but has not been properly appreciated. Only the results of the research of the upper layers of the atmosphere carried out in the years 1982 - 1991 showed a significant disappearance of the shell of this gas and a significant increase in the "ozone hole" over Antarctica. Initially, there were doubts about the actual nature of this phenomenon. Some regarded them as natural, and others as an anthropogenically conditioned phenomenon. Further research confirmed its anthropogenic nature, and freon was recognized as the ozone depleting factor.

Since the discovery of the ozone hole, its surface area has increased by 15% and the ozone content has decreased by 70%. Information obtained from monitoring conducted by satellites shows that the rate of decrease in the global amount of atmospheric ozone is currently at the level of 0.3 - 0.7% per year in the temperate climate zone and less than 0.2% in intertropical areas, i.e. together with decreases slightly over the years. At this point, it should be noted that according to ULEP estimates, a 1% reduction in the thickness of the ozone layer may result in a 6% increase in skin cancer and a 0.6% increase in eye disease. The loss of ozone, e.g. by 5%, simultaneously leads to a decrease in cereal production by 5%. Limiting the size of this phenomenon is not helped by the fact that the compounds causing the depletion of the ozone layer, i.e. freon and halon, due to their durability, cause a chain process of ozone particle decay years after their emissions have been eliminated. This means that even after the complete cessation of the introduction of freon and halon into the atmosphere, ultraviolet radiation will continue to lead to the depletion of the ozone layer for many years. Significant and beneficial revaluations in this respect were made as a result of the implementation of the provisions of the Vienna Convention of March 1985. on the protection of the ozone layer.

Human activity is also the cause of globally greater rainfall over land, which in turn contributed to the change in the salinity of near-surface ocean waters. Moreover, humans had their hands in the process of retreating, since the early 1990s, of glaciers around the globe, as well as the noticeable reduction in the area of sea ice in the Arctic. Their

activity also contributed to the melting of the surface of the Greenland ice sheet and, to a lesser extent, to the melting of the Antarctic ice sheet. Due to irrational human activities, the sea level in the world has also risen. In the last 120 years, this is an increase of 15 cm to 25 cm, and in recent years, the increase is 3.2 mm to 4.2 mm in one year. As a result of the shift of climatic zones in both hemispheres towards the poles, the growing season is gradually lengthening (on average by up to two days per decade).

In the years 2019 - 2021. The concentration of CO<sub>2</sub> in the atmosphere was the highest in the last 2 million years and amounted to about 47%. However, in the same time period, the concentration of CH<sub>4</sub> (methane) and N<sub>2</sub>O (nitrous oxide) was higher than at any time in the last 800,000 years and amounted to 156% for methane and 23% for nitrous oxide. This is undoubtedly the result of human activity, which usually increases greenhouse gas emissions, especially CO<sub>2</sub>, for profit, whim, and often due to sheer stupidity. At the same time, the same humans devastate the terrestrial and aquatic natural environment (e.g. by logging and burning forests, replacing lawns with concrete cubes, or wasteful water management, destruction of coral reefs, mindless pollution of oceans, seas and inland waters, etc.). As a consequence, a smaller percentage of the emitted carbon dioxide is absorbed by terrestrial and oceanic ecosystems, whose capacity in this respect is decreasing, and this is due to the obvious fault of humans.

Not surprisingly, over the past 50 years, ambient temperature has risen faster than over the past 2,000 years. However, in the years 2011-2021, temperatures exceeded those that occurred during a warm period lasting several centuries 6,500 years ago. In general, mean sea levels have risen faster since the beginning of the 20th century than in any other century in the last 3-4 thousand years. Despite the rapid melting of glaciers, the water in the seas and oceans has been warming up faster for about 11,000 years (i.e. since the end of the exit from the last glaciation). At the same time, the pH values of open ocean surface waters are the lowest in the last 2 million years.

One of the effects of the observed anthropogenic climate change are the heat waves that have been occurring since the middle of the last century, the frequency and intensity of which are increasing. In contrast, equally annoying waves of cold become less frequent and less dangerous. Here, too, the human influence seems obvious. In turn, the global decline in monsoon rainfall over land recorded in the second half of the last century was largely generated by anthropogenic aerosol emissions in the northern hemisphere. In the last two decades of the twentieth century, due to the increase in greenhouse gas emissions into the atmosphere, monsoon rains intensified again, as aerosol emissions gradually decreased.

The last fifty years have been marked by the increase of strong tropical cyclones, mainly in the western part of the North Pacific, which should also be included in the effects of climate change. They are also responsible for extreme heat and droughts and associated extensive fires that destroy forests, crops and human settlements. No less damage is caused by floods, not always associated with large rivers. Much damage is also caused by the increasingly frequent mudslides and landslips or collapses.

### **3 The predicted evolution of the climate picture in the years 2022 - 2100**

The analysis of available studies on the issue of climate change, including predictions about its possible appearance in the final years of this century, leads to a number of different observations. The essence of one of them is special and optimistic for humanity and all other living organisms, as well as for the planet itself. It also seems simple to implement it, which requires people to make their activities climate-neutral. Despite its simplicity, this is the only solution that can ensure normality in the further functioning of the global village. Postponing and limiting the scope of necessary changes and looking for less demanding solutions does not bode success, but leads to an inevitable disaster.

This inevitability results, in particular, from the "greenhouse effect" (also called the greenhouse effect), which, due to its specificity, causes an increase in the average temperature on Earth as a result of disturbances in heat exchange between the Earth and the upper layers of the atmosphere. These disturbances are the result of the anthropogenic accumulation of various gases in the atmosphere, which are commonly referred to as greenhouse gases. Their presence causes that the heat, instead of being radiated outside the Earth's atmosphere, accumulates in it. As a consequence, the Earth's atmosphere becomes, in a sense, the glass roof of the greenhouse, which allows solar radiation to pass through, but does not allow the heat accumulated inside to be radiated.

The most important greenhouse gases include, above all, such as:

- **carbon dioxide** - which, according to estimates, is responsible for 60 - 63% of disturbances in heat exchange between the Earth and its surroundings;
- **methane** - according to estimates, its responsibility for the above-mentioned disturbances (in terms of CO<sub>2</sub>) is at the level of 15 - 17%;
- **nitrogen oxides** – which, according to estimates, account for 4% of disturbances;
- **freon** – its share in greenhouse gas emissions is estimated at around 20%;
- **ozone** – responsible for disturbances in the low layers of the atmosphere.

*Carbon dioxide* is primarily produced by the burning of fossil fuels, the destruction of forests, and by the current pattern of agriculture, especially in South America. The inhabitants of the "global village" emit well over 18 billion tons of CO<sub>2</sub> into the atmosphere annually. On the other hand, its content in the atmosphere in recent years has increased annually by about 0.35%, which is also largely due to the grubbing up and burning of large forest complexes. Burning 1 hectare of forest releases over 700 tons of carbon dioxide into the atmosphere. Clearing and burning forests also destroys the leaves of trees, which absorb carbon dioxide as part of the photosynthesis process. Therefore, the concentration of this gas has increased from 390 ppm in 1999 to 418 ppm today.

In turn, *methane* gets into the atmosphere most often as a result of microbiological decomposition of organic matter in landfills, in municipal sewage collectors, as part of the process of decomposing green plants in swamps, in flooded rice fields, in the process of burning wood and digesting food by cattle. Studies and observations indicate a rapid increase in the concentration of methane in the atmosphere as a result of thawing along with the progressive warming of the climate, frozen swamp soils in the northern reaches of Eurasia and North America.

On the other hand, the source of *nitrogen oxide* are primarily mineral fertilizers and energy resources, but also these gases are released into the atmosphere during the combustion of green mass and fossil fuels. In turn, ozone accumulates near the surface of the earth, which is done by exhaust gases emitted by car engines, combined heat and power plants and oil refineries. The catalog of greenhouse gases also includes freon, as well as a gas recently discovered by scientists at the University of Norwich, which is a compound of sulfur, fluorine and carbon. This gas traps heat more effectively than other greenhouse gases, and its current concentration is around 7%.

The simplest solution would be to remove the accumulated greenhouse gases out of the atmosphere in a controlled manner. This variant is considered by scientists from different countries of the world, but so far without success. At the same time, eminent scientists from many countries, in particular the United States, Japan, Canada, Australia, China, Great Britain, as well as the Netherlands and many other countries, including Poland, create scenarios regarding the predicted climate change by the end of this century. In the scenario of very low greenhouse gas emissions (i.e. in a situation where the countries of the globe take actual actions to make their economies zero-emission), in the late 21st century the average global surface temperature of the globe may be 1.8°C higher than in the early years of the 20th century. In turn, in the intermediate scenario, this increase may amount to 3.5°C, while in the scenario of very high greenhouse gas emissions (at a similar level to the current level), the increase in the average global surface temperature of the Earth may even amount to 8.5°C. In the scenario of very high and medium greenhouse gas emissions, global warming will absolutely exceed the 2°C threshold, while in the low emissions scenario, exceeding this threshold is rather out of the question (this is, inter alia, the goal of the EU and Poland's climate policy).

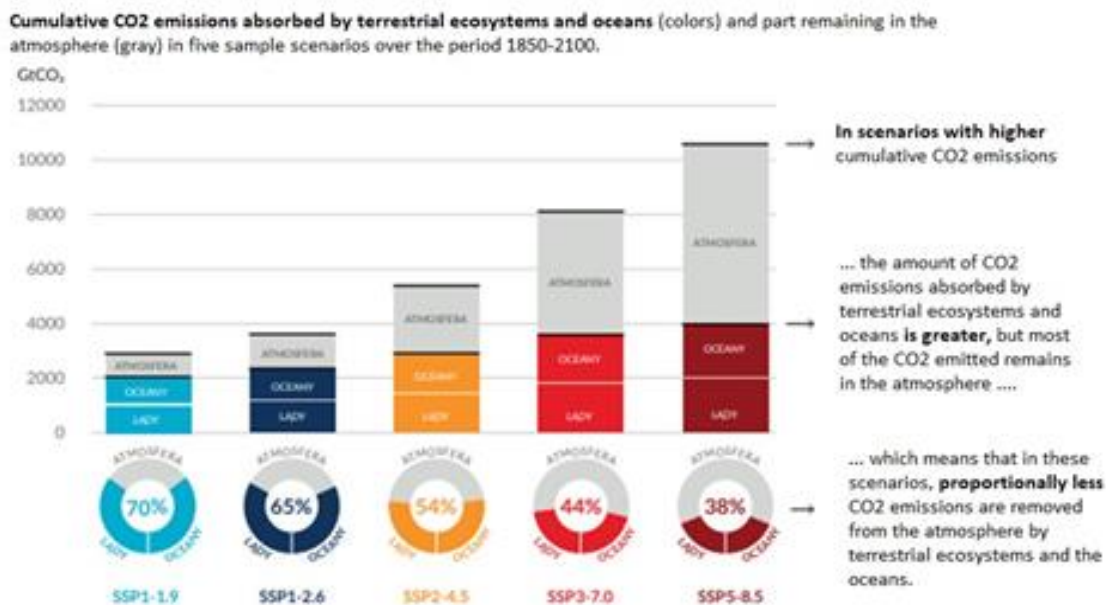
Depending on the level of greenhouse gas emissions (i.e. emission scenario: low, medium and very high), i.e. the scale of the global warming effect, the scope and strength of extreme phenomena will be shaped, in particular with regard to heat waves (e.g. Africa will continue to warm faster than the global average and record new heat records); sea heat waves and unusually heavy rainfall; increase in the number and strength of hurricanes, cyclones, whirlwinds and winds; agricultural droughts; declining ice cover in the Arctic seas, as well as permafrost and snow cover. As a result of the average global temperature, the expansion (increase in volume) of water in oceans and seas, as well as lakes, will result in flooding (this problem also applies to Europe, especially the Netherlands). It is projected that by the end of 2100 the average sea level will rise by about 55 cm and will most likely continue to rise in the coming centuries and then remain at a very high level for many thousands of years. Weather and climatic phenomena related to the excess or shortage of water will intensify, which in the light of forecasts will result in more frequent and greater floods and droughts. Depending on the scenario, the average annual precipitation in the world may increase by as much as 5-13% at the end of the 21st century compared to the end of the 20th century. In general, rainfall is projected

to increase in the Pacific around the equator and in much of the monsoon regions, while decreasing in subtropical and tropical areas. Forest fires, as well as fires in agricultural fields (mainly cereals, corn, rapeseed, but also olive orchards, etc.) will be an increasing problem.

Considering the history of our planet so far, it should be remembered that in the past there were unpredictable natural phenomena that were not related to human influence on the climate (e.g. a series of large and violent volcanic eruptions over several decades). This may also be the case today, although Putin's use of nuclear weapons in a war with Ukraine seems more likely. Natural disasters from the distant past eliminated, among others, dinosaurs, as well as many other species of fauna and flora, and significantly changed the face of our planet. However, in an unknown way, nature was able to cope with the consequences of the catastrophe, of which it was the main animator. Unfortunately, nature can be blamed for the current changes only to a small extent, because the main creator of these changes is man, who can count on nature's support, but must take the main burden of repair on his own shoulders.

#### 4 Limiting climate change

The cause of numerous climate-related problems is global warming, generated by the increase in CO<sub>2</sub> emissions, for which man is responsible. Halting warming requires reducing cumulative carbon emissions to at least net zero and substantially reducing emissions of other greenhouse gases. This is a self-evident task to be pursued at the global, national and local levels. However, the ongoing war between Russia and Ukraine and the related energy crisis, the dimension of which definitely exceeds all previous ones, may significantly hinder, and even in the case of some countries (e.g. Poland) limit the scope of activities aimed at zero CO<sub>2</sub> emissions. On the other hand, the energy crisis should accelerate the development of renewable energy sources (RES), and thus a low-carbon economy and a circular circular economy. In the event of a significant reduction of CO<sub>2</sub> emissions into the atmosphere by man, the support of nature will increase, as the fraction of carbon dioxide absorption will be greater, which is graphically presented in Figure 1.



**Figure 1.** Cumulative anthropogenic CO<sub>2</sub> emissions absorbed by oceans and land by 2100 for five sample scenarios

**Źródło:** Podsumowanie dla Decydentów (w:), Zmiany Klimatu 2021, Fizyczne Podstawy Naukowe. Wkład I Grupy Roboczej do Szóstego Raportu Oceny Międzynarodowego Zespołu ds. Zmiany Klimatu, Warszawa 04.11.2021, s. 27

As CO<sub>2</sub> emissions increase (moving to the right), so does the amount of CO<sub>2</sub> released into the atmosphere, but so does its absorption by land and oceans. However, the fraction of CO<sub>2</sub> entering the atmosphere increases more than the fraction of carbon dioxide that is absorbed by the oceans and land. This relationship is clearly marked in the analyzed figure 1. It should be noted, however, that in the case of all 5 scenarios presented in this figure, the CO<sub>2</sub> emission is at a level higher than zero net. Therefore, in each of these cases, climate warming will continue to progress. This means that it is necessary to intensify actions limiting carbon dioxide emissions and other greenhouse gases to a greater extent. You also need to be aware that net-zero CO<sub>2</sub> emissions are the minimum, as to reduce the "extreme madness" of the climate you need to aim for a net level of emissions well below zero, and preferably one that makes human activity climate-neutral.

## 5 End

The considerations carried out in this article have shown that people often act in a rational way in pursuit of immediate benefits. Today, providing examples of such ill-considered, and at the same time, harmful activity does not cause much difficulty, because the rich literature on the subject, as well as other sources, provide a lot of them. In general, they are related to the use of fossil fuels as a source of energy by man, forest burning and irrational forest management, pollution of seas, oceans and other water reservoirs, clearing of jungles and destruction of large river basins, especially in South America. In addition, there are pollutants emitted by air, water and road transport, as well as fertilizers, popular "cinderella" and many others, the list of which is very long and constantly enriched. Also the effects of these activities are easy to notice, and their catalog is also very rich and constantly enriched with new ones. The problem of global warming has become so complicated that the current fuel crisis caused by Putin makes it even worse. The growing scale of the negative effects of climate warming on humans and the natural environment requires immediate and consistent action. Betting on nature that it will repair the evil caused by man is not scientifically justified, which is also confirmed in this article. Undoubtedly, nature will support man in his actions, but he must reduce greenhouse gas emissions to the lowest possible levels (in the case of CO<sub>2</sub>, this means net below zero). Extensive social education and actual competences of those managing the environment, economy and other areas of life of the human population in the "global village" are also necessary. Any ignorance in this regard usually ends in a disaster, as exemplified by the recent problems of the Odra river ecosystem.

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