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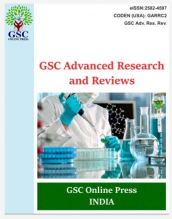


(Review Article)

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# Global warming: Causes, impacts and urgent strategies for a sustainable future: A review

Najmaldin Ezaldin Hassan *

*Department of Civil and Environment, College of Engineering, University of Zakho, Kurdistan region, Iraq.*

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## Abstract

Global warming is defined as a rise in Earth's average temperature. As the Earth gets warmer, disasters such as droughts, hurricanes, and floods are becoming increasingly common. Most scientists, engineers, and activists express deep concern about changes in the planet's overall climate. The average air temperature above the surface of the Earth has risen by just below 1 degree Celsius, or 1.3 degrees Fahrenheit, over the past 100 years.

Deforestation exacerbates the severity of global warming. The ocean, which holds about 50 times more carbon than the atmosphere, is an enormous carbon sink. However, the seas are no longer able to store carbon as effectively as they have in the past. Burning fossil fuels such as natural gas, oil, coal, and gasoline increases atmospheric carbon dioxide levels, and carbon dioxide is a major contributor to the greenhouse effect and global warming. Climate change will increase the number of people who suffer from heatwaves, floods, hurricanes, and droughts, leading to higher rates of death, illness, and injury.

The threat of global warming continues to cause severe damage to the Earth's environment. Many people still do not fully understand the implications of global warming or consider it a significant problem for the future. However, global warming is already happening, and some of its devastating consequences are already being felt. It significantly impacts biodiversity and disrupts ecological balance. Due to the dangerous effects of global warming, many strategies need to be established. The report discusses global warming, outlines its causes and risks, and proposes solutions to this urgent issue. Above all, it is crucial to seriously consider alternative energy sources (biomass, wind, hydro, geothermal, and solar). One of the key strategies to counter the ever-increasing global warming is the identification and use of renewable energy sources.

**Keywords:** Global warming; Environmental impact; Mitigation strategies; Public awareness; Alternative and Renewable energy sources

## 1. Introduction

### 1.1. What is Global Warming?

Global warming is a gradual increase in Earth's average atmospheric temperature attributed to the greenhouse effect, which is induced by higher levels of methane, carbon dioxide, chlorofluorocarbons, and other contaminants [1]. Global warming is one of the 21st century's most contentious scientific concerns, threatening the very structure of global society. The dilemma is that global warming is not only a scientific issue but also involves economics, geopolitics, local politics, psychology, and individual lifestyles. Scientists have discovered that several greenhouse gases are responsible for global warming, and humans produce these gases in various ways. Many of these gases come from the combustion

* Corresponding author: Najmaldin Ezaldin Hassan

of fossil fuels in vehicles, factories, and electricity production. Carbon dioxide ($CO_2$) is the most prominent greenhouse gas [2]. Other contributors include methane emitted from landfills and agriculture (especially from the digestive systems of grazing animals), nitrous oxide from fertilizers, gases used in refrigeration and industrial processes, and deforestation, which reduces the capacity of forests to store $CO_2$ and other gases. Different greenhouse gases have varying abilities to absorb heat. Some are more effective at trapping heat than $CO_2$. For example, a methane molecule traps over twenty times more heat than a $CO_2$ molecule, while nitrous oxide is 300 times more effective than $CO_2$. Certain gases, such as chlorofluorocarbons (which have been banned in many parts of the world because they also damage the ozone layer), have a heat-trapping potential a thousand times greater than $CO_2$. However, because their concentrations are much lower than $CO_2$, these gases contribute less overall heat to the atmosphere than $CO_2$ [2]. There is clear evidence that, over the past half million years, atmospheric carbon dioxide levels have reached their highest levels ever, possibly even longer. Scientists believe this contributes to the Earth warming more quickly than at any other time in history. According to the Intergovernmental Panel on Climate Change (IPCC), there is evidence of a 0.6°C rise in global temperatures and a rise in sea levels over the 20th century. The IPCC projects that global temperatures could rise between 1.4°C and 5.8°C, and by the year 2100, sea levels could increase by 20 cm to 88 cm. Consequently, weather patterns will become less stable, and extreme climatic events such as hurricanes, floods, and droughts will become more frequent. This could lead to potentially devastating effects on human society, including drastic changes in health, food security, infrastructure, water resources, coastal regions, and biodiversity. If global warming continues unabated, it will disproportionately affect the world's poorest people [1, 3].

A general overview of the global warming process is illustrated in Fig. 1. The greenhouse effect is a mechanism through which greenhouse gases in the atmosphere absorb and re-radiate infrared energy from the Earth. This process transfers energy to the lower atmosphere and the ground, resulting in a temperature increase that would be higher than if warming were only due to direct solar radiation.

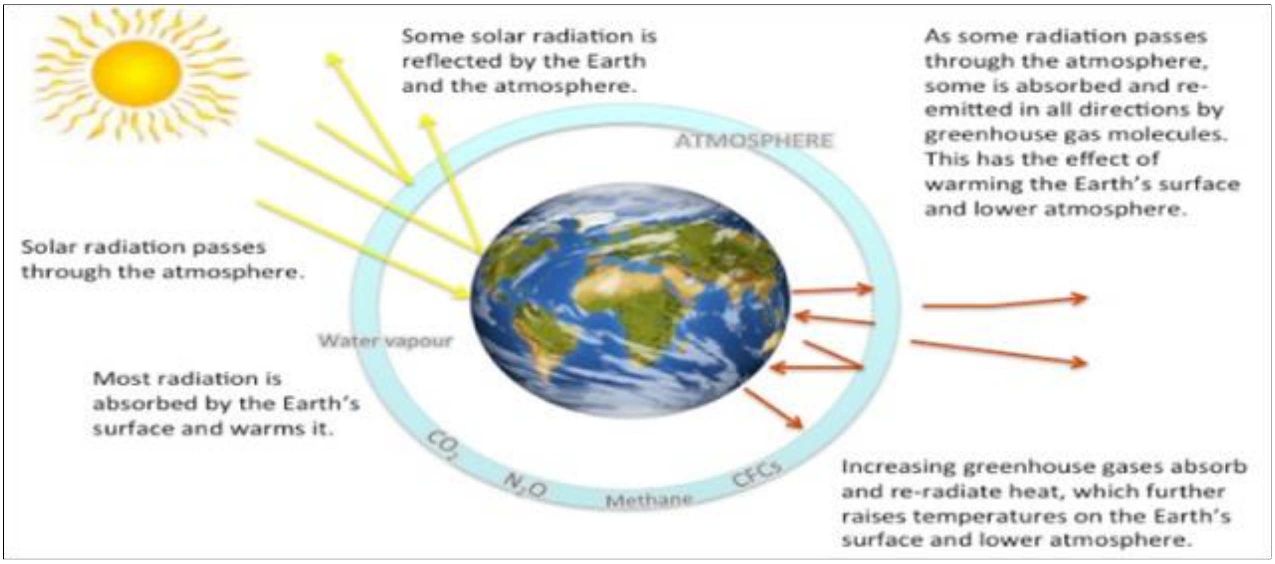


**Figure 1** Global Warming Mechanism

### 1.2. Climate change

Climate change refers to long-term changes in Earth's climate, including variations in average temperature, rainfall, and precipitation on both natural and regional scales. It is influenced by gradual changes in factors such as the sea, the moon, Earth's orbit around the sun, and the sun's energy production. Climate change is governed by Earth's energy balance and atmospheric conditions. It is caused by various factors, including biotic processes, changes in solar radiation received by Earth, volcanic eruptions, and plate tectonics, as illustrated in Figure 2.

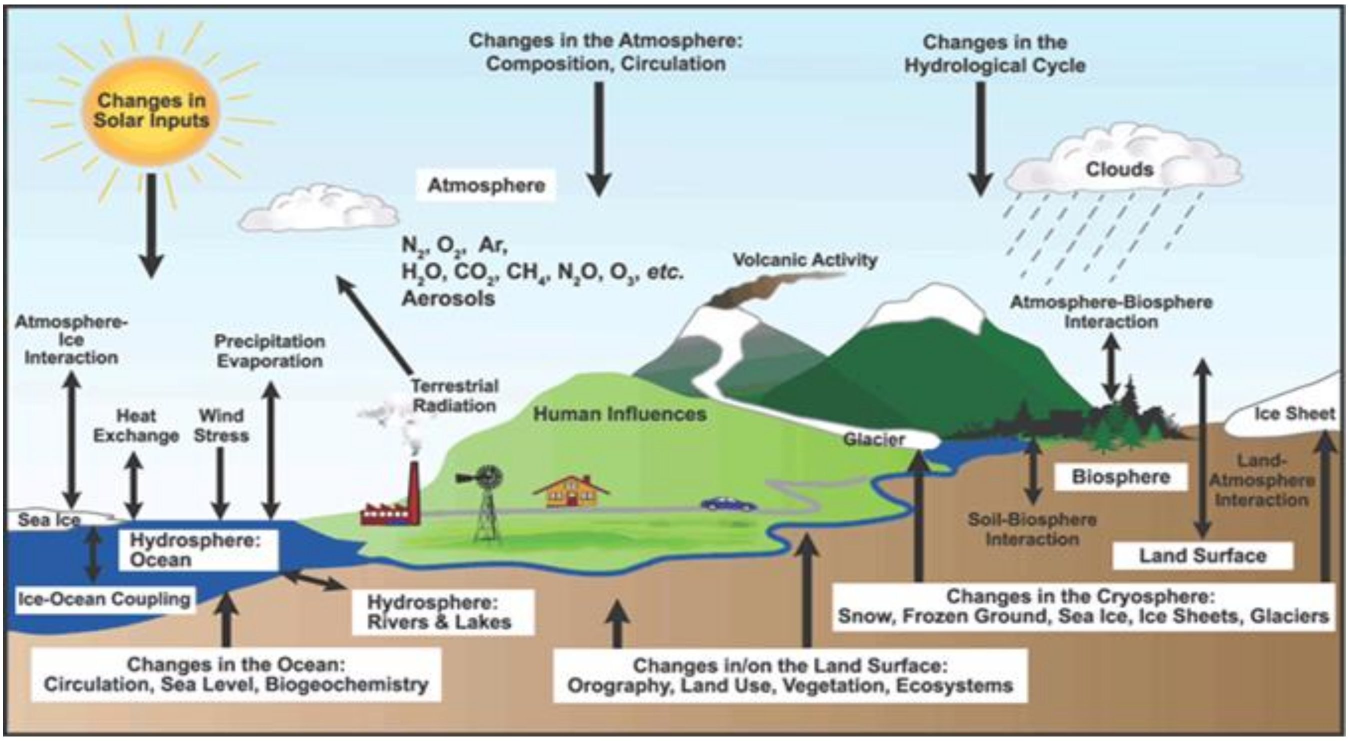


**Figure 2** Climate change

People often confuse global warming with climate change. While they are related and similar, they are not exactly the same. Global warming specifically refers to the recent increase in Earth's average temperature. Climate change, on the other hand, encompasses a broader range of changes, including variations in wind patterns, rainfall, seasonal durations, and the intensity and frequency of extreme weather events such as floods and droughts.

Most scientists believe that climate change in the near future will be primarily driven by human-induced greenhouse gas emissions. Some global warming skeptics argue that while global warming may have a minor impact, natural climate change is occurring on human timescales, and we should be prepared to adapt to it. Climate change can manifest in several ways, including increases in regional and global temperatures, shifts in rainfall patterns, expansion and contraction of ice sheets, and fluctuations in sea levels. These regional and global climate changes are responses to both external and internal forcing processes. For example, changes in atmospheric carbon dioxide content can modulate the greenhouse effect, an internal forcing mechanism. In contrast, long-term variations in Earth's orbit around the sun are an example of an external forcing mechanism, affecting the regional distribution of solar radiation to Earth [1].

## 2. Causes of global warming

Greenhouse gases are the primary cause of global warming. These gases include carbon dioxide, nitrous oxides, methane, and certain compounds containing chlorine and bromine. The accumulation of these gases in the atmosphere disrupts radiative equilibrium, leading to the heating of Earth's surface and lower atmosphere. Greenhouse gases absorb some of Earth's incoming radiation and re-radiate it back to the surface [2].

Another significant cause of global warming is the depletion of the ozone layer, which is partly due to gases containing chlorine. These gases dissociate chlorine atoms when exposed to ultraviolet light, which then catalyze the destruction of ozone. In addition, aerosols contribute to global warming in two ways. First, they scatter and absorb solar and infrared radiation. Second, they can alter the microphysical and chemical properties of clouds, affecting their lifetime and duration. While scattering of solar radiation by aerosols can have a cooling effect on the planet, the absorption of solar radiation by aerosols actively warms the atmosphere, preventing Earth's surface from absorbing sunlight.

Human activities contribute to aerosol levels in the atmosphere in various ways. For example, dust is a by-product of agricultural activities. The burning of biomass produces carbon droplets and soot particles. Industrial processes generate a wide range of aerosols depending on the materials being processed or burned. Additionally, exhaust emissions from various forms of transportation contain a mixture of contaminants that are either present as aerosols or are converted into aerosols through chemical reactions in the atmosphere [4].

Causes of global warming divided in to natural and man-made

## 2.1. Natural causes

### *2.1.1. Solar activity*

It is widely acknowledged that significant fluctuations in solar radiation and events such as solar flares or sunspots may influence global temperatures. For example, a weaker sun is believed to have contributed to the "Little Ice Age" in the seventeenth century, during which the average global temperature was about 1 degree Celsius cooler than today. Solar activity, including the 11-year sunspot cycle, varies in phases. These variations in solar behavior can shift the Earth's magnetic field. This magnetic field plays a crucial role in deflecting cosmic rays (charged particles from distant stars) away from Earth. When the sun's activity diminishes and its magnetic field weakens, more cosmic rays penetrate the solar system and reach Earth's lower atmosphere. These cosmic rays ionize small particles in the air, which then aggregate into water droplets and form clouds. Low clouds, when sufficiently thick, can effectively reflect the sun's energy back into space. An increase in Earth's cloud cover can lead to a decrease in global temperatures. Additionally, variations in solar irradiance, such as changes in ultraviolet and visible wavelengths, may be correlated with changes in ambient temperatures. The exact relationship between solar radiation and global warming, and the relative importance of solar radiation compared to greenhouse gases in driving global warming, remains a subject of ongoing research and debate. Climate models are employed to study the sun's role in recent climate changes [5].

### *2.1.2. Natural deforestation*

Natural forest fires can impact global temperatures, particularly large-scale fires that occur over extended periods. When vegetation burns, accumulated carbon is released into the atmosphere, increasing the concentration of greenhouse gases such as carbon dioxide. These greenhouse gases absorb solar energy, ultimately contributing to atmospheric warming. Additionally, forest fires produce soot and harmful gases, which contribute to air pollution [5, 6].

### *2.1.3. Permafrost melting*

Permafrost, or cryotic soil, is soil that has been at or below the freezing point of 0°C (32°F) for two or more years. It is primarily found in high latitudes, particularly in and around the Arctic and Antarctic regions. However, significant amounts of carbon can also be deposited at high altitudes in lower latitudes. Surface ice is not always present, especially in areas with non-porous bedrock, but when it does occur, it may exceed the hydraulic saturation capacity of the surface material. Permafrost accounts for 0.022% of total Earth ice [1] and covers 24% of the Northern Hemisphere's exposed land.

Permafrost is at risk of melting due to global warming, which can release trapped carbon in the form of carbon dioxide and methane, both potent greenhouse gases. This melting can lead to structural issues such as flooding, lake depletion, landslides, and subsidence. It can also alter the composition of plant species at high latitudes. According to one group of scientists, a global temperature increase of 1.5°C (2.7°F) above current levels could trigger the thawing of permafrost in Siberia [6].

### *2.1.4. Eruption of the volcano*

As volcanoes erupt, they release a mixture of gases and particles into the air, including water vapor ($H_2O$), carbon dioxide ($CO_2$), sulfur dioxide ($SO_2$) from high-temperature volcanic gases, and hydrogen sulfide ($H_2S$) from low-temperature volcanic gases. Other gases emitted can include nitrogen, hydrogen, methane, argon, helium, neon, and carbon monoxide.

Airborne aerosols can influence the climate in two significant ways. First, they can distribute and absorb solar and infrared radiation. Second, they can alter the microphysical and chemical properties of clouds, potentially affecting their lifespan and extent. The dispersion of solar radiation by aerosols tends to cool the planet, while the absorption of solar radiation by aerosols warms the atmosphere, preventing the Earth's surface from absorbing sunlight. Additionally, greenhouse gases and volcanic carbon dioxide can contribute to global warming [7].

**Figure 3** Volcanic Eruption

*2.1.5. Animal methane emissions*

As part of their normal digestive processes, domestic animals such as cows, buffalo, pigs, goats, and camels produce large amounts of methane ($CH_4$). Additionally, methane is generated when animal manure is stored or handled in lagoons or holding tanks. These emissions are considered human-related because humans raise these animals for food. Agriculture is the primary source of methane pollution worldwide.

## 2.2. Causes Manmade

*2.2.1. The burning of fossil fuels*

Fossil fuels are hydrocarbons formed from the remains of dead plants and animals, including fuel oil, coal, and natural gas. The term "fossil fuel" also includes natural resources containing hydrocarbons that are not derived from biological sources. The most significant driver of global warming, according to the EPA, is carbon dioxide. In the United States, over 90 percent of greenhouse gas emissions result from fossil fuel combustion [8].

**Figure 4** Burning fossil fuels

*2.2.2. Manmade Deforestation*

Deforestation caused by human activity is also a significant contributor to global warming [9]. As the number of plants on Earth decreases, the amount of carbon dioxide in the atmosphere increases. Additionally, decaying plant matter releases accumulated carbon, further contributing to atmospheric carbon levels, especially during the clearing of forests or grasslands for construction. Tropical deforestation accounts for about 20% of global greenhouse gas emissions [10].

*2.2.3. Uses of fertilizer*

During the production of nitrogen fertilizer, greenhouse gases such as carbon dioxide, methane, and nitrous oxide are released. Each time humans apply fertilizer to the soil, nitrogen oxide escapes into the air. After carbon dioxide and methane, nitrous oxide has become the third most important greenhouse gas [11], making fertilizer use one of the major contributors to global warming in agriculture [12].

*2.2.4. Mining*

Coal mining can account for eight percent of all methane emissions. Oil and coal production allow methane to escape into the atmosphere. Stored gases are released into the atmosphere whenever the soil is disturbed [13].

## 3. Greenhouse gases (GHG)

A greenhouse gas (GHG) is an airborne gas that absorbs and emits radiation within the thermal infrared spectrum. This process is the root cause of the greenhouse effect. Water vapor, carbon dioxide, methane, nitrous oxide, ozone, and CFCs are the primary greenhouse gases in Earth's atmosphere. Without greenhouse gases, Earth's surface would be about 33°C cooler, roughly 59°F below the current average temperature of 14°C (57°F). Greenhouse gases are those capable of absorbing and releasing infrared radiation [14], but not radiation within or near the visible spectrum.

The most concentrated greenhouse gases in Earth's atmosphere are:

### 3.1. Chlorofluorocarbons (CFCs)

Chlorofluorocarbons are industrial chemical compounds used in various applications, but they are now primarily restricted by international agreements due to their role in degrading the ozone layer when processed and released into the atmosphere. They are also greenhouse gases [15].

### 3.2. Carbon Dioxide ($CO_2$)

Carbon Dioxide is a small but very significant component of the atmosphere. Carbon dioxide is released through natural processes such as respiration and volcanic eruptions, as well as human activities including deforestation, land use changes, and fossil fuel burning [16]. Since the Industrial Revolution, human activities have increased atmospheric $CO_2$ concentrations by about 25%. $CO_2$ is a critical long-lived greenhouse gas contributing to climate change.

### 3.3. Water Vapor ($H_2O$)

Water Vapor is the most abundant greenhouse gas and plays a crucial role in the climate system. As the Earth's atmosphere warms, water vapor increases, leading to more cloud formation and precipitation. These processes are essential feedback mechanisms in the greenhouse effect.

### 3.4. Nitrous Oxide ($N_2O$)

Nitrous Oxide is a potent greenhouse gas produced by soil cultivation activities, particularly through the use of industrial and organic fertilizers, the combustion of fossil fuels, nitric acid production, and biomass burning.

### 3.5. Methane ($CH_4$)

Methane is a colorless, odorless gas found naturally and produced through certain human activities. It is the simplest member of the hydrocarbon paraffin series and is one of the most potent greenhouse gases.

### 3.6. Ozone ($O_3$)

Ozone is formed in the Earth's atmosphere through ultraviolet (UV) light and electrical discharges from dioxygen. It is present in low concentrations in the troposphere but reaches its highest concentration in the stratospheric ozone layer, where it absorbs most of the Sun's ultraviolet radiation.

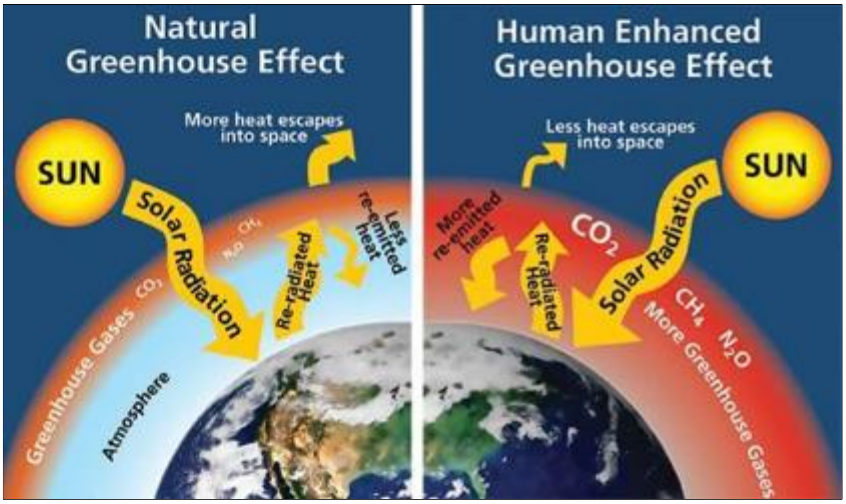


**Figure 5** Types of greenhouse effects

## *4.* The Contribution of gases

The contribution of gases to the greenhouse effect is influenced by their characteristics, abundance, and any indirect effects they may cause. For example, the direct radiative effect of methane is about 20 times greater than that of the same mass of carbon dioxide over a 100-year time frame. However, methane is present in much smaller quantities, so its overall direct radiative effect is lower, partly due to its shorter atmospheric lifespan. Methane also has a significant indirect radiative effect beyond its direct influence, as it contributes to the formation of ozone. Some studies suggest that due to this impact, the contribution of methane to climate change is at least double previous estimates [17].

**Table 1** The most important gases, measured by their direct contribution to the greenhouse effect

| **Compound** | **Contribution (%)** | **Formula** |
|---|---|---|
| Water vapor and cloud | 36-72% | $H_2o$ |
| Carbon dioxide | 9–26% | $CO_2$ |
| Chlorofluorocarbons | 7-17% | CFCs |
| Methane | 4–9% | $CH_4$ |
| Nitrous oxide | 4-8% | $N_2O$ |
| Ozone | 3–7% | $O_3$ |

Certain greenhouse gases include arsenic hexafluoride, hydrofluorocarbons, perfluorocarbons, and the major greenhouse gases mentioned above. Many greenhouse gases are not consistently monitored. For example, nitrogen trifluoride has a high potential for global warming but is found only in trace amounts [18].

## 5. Global warming effects

- Physical impacts
- Biological Impacts
- Social effects

### 5.1. Physical Impacts: This can be divided into

#### *5.1.1. Extreme weather events*

Extreme weather is a phenomenon associated with global warming. According to Climate Central, extreme weather events such as heat waves, droughts, blizzards, and rainstorms are expected to occur more frequently and with greater intensity due to global warming. Climate models predict that global warming will lead to significant changes in climate patterns worldwide, including adjustments in wind patterns, annual rainfall, and fluctuations in seasonal temperatures. Since ambient greenhouse gas levels are likely to remain high for many years, these changes are anticipated to persist for decades or longer [8, 19].

*5.1.2. Ice melt*

The decline of Arctic Sea ice is one of the most dramatic effects of global warming. Scientists recorded the smallest amount of Arctic ice cover ever in 2012. Some analysts predict that the Arctic Ocean could become ice-free during the summer months within a few years [20]. The thawing of various types of Arctic permafrost this century could release large amounts of carbon into the atmosphere. Climate models suggest that temperatures could rise up to 1,450 km (900 mi) inland during periods of rapid sea-ice loss, increasing the rate of terrestrial permafrost thaw and potentially affecting carbon and methane release [21].


**Figure 6** Symbolic Representation of How Earth's Melting Contributes to Global Warming

*5.1.3. Sea levels and ocean acidification*

Several factors contribute to rising sea levels, including seawater thermal expansion, the melting of glaciers and ice sheets, and changes in groundwater storage due to human activities. The rise in sea level is a key indicator of global warming [22]. According to the EPA, global sea levels have risen by about 8 inches since 1870 [10]. Sea-level rise is expected to continue for centuries. In 2013, the Intergovernmental Panel on Climate Change (IPCC) projected that sea levels could rise by 26 cm to 82 cm during the 21st century. Additionally, ocean acidification is another consequence of global warming. As $CO_2$ levels increase, some of this gas is absorbed by the oceans, leading to higher seawater acidity. According to the EPA, ocean acidity has increased by about 25 percent since the early 1700s, and if current trends continue, coral reefs in areas where they are now common may become increasingly rare [23].

### 5.2. Biological Impacts

*5.2.1. Impact on plants*

Global warming is predicted to have significant and widespread effects on Earth's biodiversity. Due to rising temperatures, many plant species are already shifting their ranges northward or to higher altitudes. Temperature increases can push many physiological processes in plants, such as photosynthesis, to their upper limits. Extreme temperatures can be harmful when they exceed a plant's physiological tolerance. Increased atmospheric $CO_2$ concentration also affects photosynthesis, resulting in improved plant water use efficiency but decreased photosynthetic ability and growth. This can lead to plants becoming less nutritious [24]. Climate change is expected to remain a major driver of potential changes in plant biodiversity [25].

*5.2.2. Impact on animals*

As a major driver of speciation and extinction cycles, global warming has a profound direct effect on terrestrial animals. Animals are responding to climate change through migration, adaptation, or, in some cases, extinction. For example, during a drought in northern Kenya, cattle have died, highlighting the severe impacts of extreme weather [26]. Migration is a natural response to climate change, with species capable of long-distance movements likely to alter their ranges. Migratory birds and insects are arriving at their summer feeding and nesting grounds several days or weeks earlier than they did in the 20th century. These migrations often follow changes in temperature, altitude, and other environmental factors due to global warming. Phenological changes, which refer to shifts in the timing of biological events, may be inherited or not. Such changes often involve adjustments in the timing of reproduction, mating, migration, and feeding.

If left unchecked, these and other impacts of global warming are likely to contribute to the extinction of one-third of animal species from their current ranges by 2080 (Natural Climate Change Journal, 2013) [27].

**Figure 7** Dead and dying cattle in northern Kenya during a drought

### 5.3. Social Impacts

While the effects of global warming on the natural world are severe, the potential impacts on human society may be even more catastrophic [28]. Agricultural systems are likely to face significant challenges. Although growing seasons may extend into some areas, the combined effects of drought, severe weather, reduced snowmelt, increased pests, lower groundwater tables, and loss of arable land could lead to severe crop failures and food shortages. This could disrupt international food markets, potentially leading to famines, food riots, political instability, and civil unrest. Additionally, the impact of global warming on human health is expected to be significant. Global warming poses a wide range of health risks that could become critical if climate change continues on its current trajectory. Poor and low-income communities are particularly vulnerable, facing higher levels of health risks and fewer resources to cope with environmental changes. Global warming can also cause displacement due to increased frequency and intensity of weather-related disasters, which destroy homes and environments, forcing people to seek shelter and sustenance elsewhere. Climate change impacts such as desertification and rising sea levels are gradually eroding livelihoods and pushing people to leave their traditional homelands for more habitable areas [29].

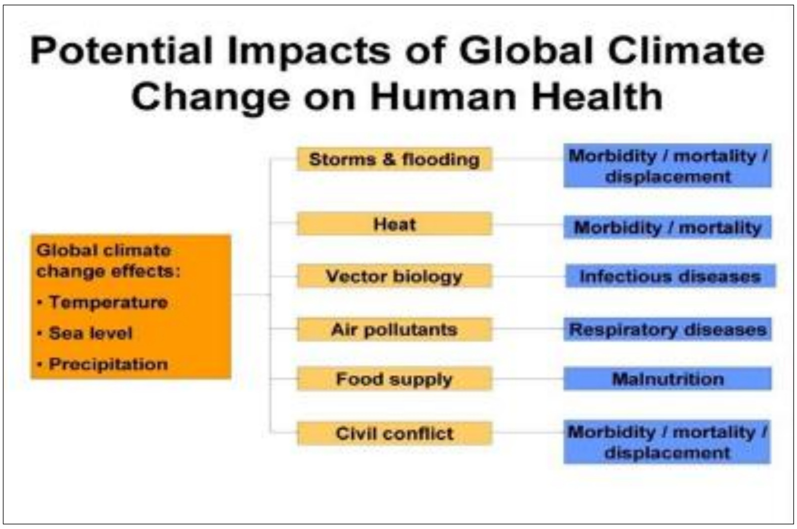


**Figure 8** Potential impacts of global climate change on human health

## 6. Global Warming Mitigation

Mitigation refers to efforts to reduce or avoid greenhouse gas emissions, thereby limiting the potential severity of global warming [30]. It may also involve attempts to remove greenhouse gases from the atmosphere [31]. Mitigation strategies include the adoption of new technologies, the use of renewable energy sources, behavioral changes, and improvements in energy efficiency. These efforts require a variety of methods and techniques.

## 6.1. Alternative sources of energy

### *6.1.1. Renewable energy*

Renewable energy includes natural phenomena such as sunlight, water, tides, plant growth, and geothermal heat [32]. This energy is derived from continuous natural processes, either directly from the sun or from heat generated deep within the Earth. Renewable energy sources include solar, wind, marine, hydropower, biomass, geothermal energy, and renewable biofuels, as well as hydrogen-generated electricity and heat. These technologies face challenges related to capital costs, financing, public perception, and the long-standing reliance on fossil fuels. However, the adoption of renewable energy has expanded much faster than anticipated [33, 34]. Research indicates that most renewable energy technologies have improved in terms of performance and cost, and their role in reducing air pollution and ensuring energy security outweighs potential disadvantages.


**Figure 9** Using renewable energy sources to save the earth from global warming

### *6.1.2. Nuclear energy*

Nuclear energy is another option due to rising fossil fuel costs and concerns about greenhouse gas emissions. However, the Fukushima nuclear disaster in Japan and subsequent shutdowns of other nuclear facilities have raised concerns about the future of nuclear power.

## 6.2. Energy efficiency and conservation

Efficient use of energy, often referred to as "energy efficiency," involves reducing the amount of energy required to produce products and services. For example, insulating a home reduces the energy needed for heating and cooling, while fluorescent lights and natural skylights use less energy than traditional incandescent bulbs. Energy efficiency is a cost-effective strategy for supporting economic growth without increasing energy consumption. Energy conservation, which involves using less energy overall, can be achieved through behavioral changes and improvements in energy efficiency. For example, heating a space less in winter or driving less are forms of conservation. While the line between energy efficiency and conservation can be blurry, both are important from an environmental and economic perspective, especially when aimed at reducing fossil fuel use [35].

## 6.3. Negative emissions and sinks

Negative emissions refer to the permanent removal of carbon dioxide from the atmosphere, such as direct air capture and storage of $CO_2$ in underground geological formations. A carbon sink is a natural or artificial reservoir that accumulates and stores carbon-containing chemical compounds, such as a growing forest.

*6.3.1. Reforestation*

Reforestation, a form of carbon sink, involves the natural or deliberate replenishment of forests that have been depleted, typically due to deforestation. Forests play a critical role in the global carbon cycle by absorbing carbon dioxide through photosynthesis. As terrestrial carbon sinks, forests remove significant amounts of this greenhouse gas from the atmosphere. Despite the continued production of anthropogenic carbon, forests absorb about three billion tons of carbon annually, accounting for roughly 30% of all fossil fuel carbon dioxide emissions. Increasing global forest cover could help offset the effects of global warming.

*6.3.2. Carbon capture and storage (CCS)*

Carbon capture and storage (CCS) is a method of reducing global warming by capturing carbon dioxide from large point sources, such as power plants, and storing it safely rather than releasing it into the atmosphere. The IPCC estimates that CCS could contribute between 10% and 55% of the total worldwide carbon reduction effort over the next 90 years. CCS is a crucial technology for $CO_2$ savings in power generation and industry, though operating a CCS-equipped coal-fired power plant requires up to 40% more energy than a conventional plant. Nevertheless, CCS can theoretically capture about 90% of the carbon emitted by the plant [36], as shown in Fig. 10.

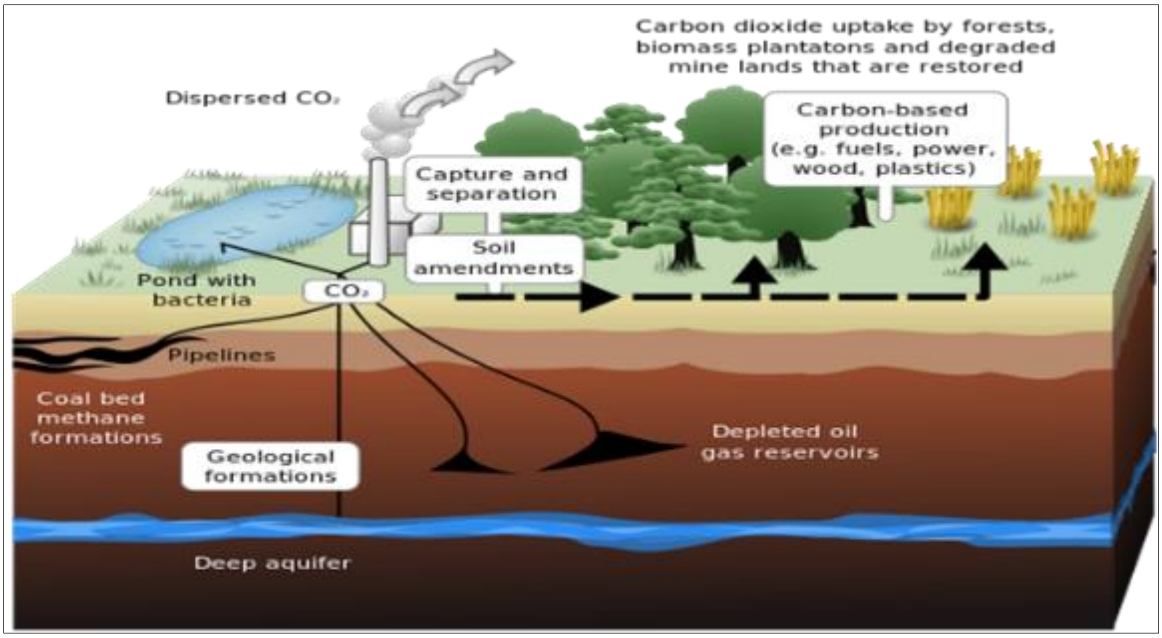


**Figure 10** Carbon capture and storage (CCS)

*6.3.3. Negative carbon dioxide emissions*

Removing carbon from the atmosphere can involve various methods, including direct air capture, biochar, carbon capture and storage, bioenergy, and enhanced weathering technologies. These approaches are sometimes referred to as sink variations or mitigation strategies [37]. Along with other mitigation measures, carbon sinks are considered essential for achieving target carbon dioxide levels in the atmosphere, particularly when combined with negative carbon emissions.

### 6.4. Geoengineering

Geoengineering involves the exploration, development, production, and exploitation of subsurface earth resources, as well as the design and construction of earthworks.

*6.4.1. Solar radiation management*

This geoengineering method involves reflecting more of the Sun's rays back into space. One approach could be to inject sulfur aerosols into the upper atmosphere, where they would mimic the reflective properties of volcanic ash, thus reducing the amount of solar radiation reaching the Earth [38].

#### *6.4.2. Iron seeding in the ocean*

Iron seeding is a geoengineering technique that promotes the growth of phytoplankton near the ocean surface. Phytoplankton absorb carbon dioxide during photosynthesis, and when they die (after about 60 days), the carbon they have absorbed sinks to the ocean floor. Pumping iron into the ocean to stimulate phytoplankton growth could potentially help mitigate global warming.

#### *6.4.3. Imitating volcanic eruptions*

This method involves releasing millions of tons of sulfur dioxide gas into the atmosphere to create a haze that blocks some of the Sun's radiation. Many scientists believe that injecting sulfur into the atmosphere could similarly block solar radiation and cool the planet. However, opponents of this method caution that these technologies are unproven and may provide an excuse for hesitant countries to avoid reducing emissions.

### 6.5. Sector-specific mitigation

Energy-efficient transportation technologies, such as plug-in hybrid electric vehicles and hydrogen-powered cars, can reduce petroleum consumption and carbon dioxide emissions. Shifting from air and truck transport to electric rail can significantly lower pollution levels [39]. Carbon emissions from electric vehicles can be further reduced if the electricity they use is generated from low-carbon energy sources. In the housing and building sector, emissions depend primarily on the total building area and climate. Government-supported energy efficiency measures, such as passive solar building design, low-energy building techniques, and zero-energy building construction, can make a significant impact. Existing buildings can be made more energy-efficient through insulation, high-efficiency appliances, and other upgrades. Additionally, painting buildings with light colors, planting trees, and using other methods to cool buildings can reduce the need for air conditioning, saving energy [40].

## 7. Recommendations to control global warming

### 7.1. Reduce, Reuse, and Recycle

Reusing and recycling various items in our daily lives can help mitigate unnatural changes in the climate. Reduce waste by purchasing reusable rather than disposable goods. Opt for minimally packaged products to cut down on waste, and make a habit of reusing paper, newspapers, plastic, glass, and aluminum containers whenever possible.

### 7.2. Plant more trees and stop deforestation

If possible, plant trees, as they absorb carbon dioxide and release oxygen through photosynthesis. This simple action can help combat climate change by reducing the amount of carbon dioxide in the atmosphere and mitigating the greenhouse effect.

### 7.3. Use the "Off" switch

Conserve electricity and reduce global warming by turning off lights when leaving a room and using only as much light as needed. Ensure that appliances like TVs, video players, stereos, and machines are turned off when not in use. Additionally, conserve water by turning off the tap while brushing your teeth, shampooing, or washing your car.

### 7.4. Switch to compact fluorescent light bulbs

Replacing incandescent bulbs with energy-efficient compact fluorescent light (CFL) bulbs can significantly reduce carbon dioxide emissions and save up to 60% of energy.

### 7.5. Use alternative energy sources

Consider using alternative energy sources such as solar power and wind energy. These renewable sources can replace fossil fuels and help reduce overall greenhouse gas emissions.

### 7.6. Use less air conditioning and heating

Improve home insulation, including walls and attics, and use weather stripping or caulking around doors and windows to cut heating costs by over 25%. Adjust heating and cooling settings to moderate levels and turn off the heat during the night or when not at home.

### 7.7. Drive smart and drive less

Reduce emissions by driving less. Opt for walking, cycling, or using public transportation. Join carpooling options and ensure your vehicle is well-maintained to operate efficiently.

### 7.8. Choose energy-efficient products

When purchasing new items, select products that offer good energy efficiency, such as cars with high gas mileage. Avoid products with excessive or non-recyclable packaging.

### 7.9. Promote environmental responsibility

Encourage family, friends, and colleagues to practice recycling and energy conservation. Advocate for environmentally friendly programs and policies by engaging with public officials and supporting sustainable practices.

## 8. Conclusion

The scientific and environmental communities agree on the harsh reality of global warming and the human factors driving it. The rapid increase in greenhouse gases is problematic, as it affects the environment faster than many living organisms can adapt. This changing and increasingly complex world presents significant challenges for all forms of life.

The report discussed here only scratches the surface of the complex field of science and engineering related to global warming. It is a serious threat that demands effective measures to address it. Global warming poses significant problems not only for humans but also for animals and plants. Melting polar ice caps can lead to widespread flooding, while rising sea levels threaten agriculture and fishing industries. Additionally, global warming results in more extreme weather events, increased precipitation followed by prolonged dry spells, changes in plant and animal survival rates, and the depletion of water supplies from glaciers.

Scientists are observing these changes occurring more rapidly than previously anticipated. To address these issues, timely remedial actions are necessary, including the adoption of renewable energy sources and efforts to prevent deforestation. To effectively tackle this threat, innovative solutions must be pursued.

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