Atmospheric and Climate Sciences, 2026, 16(2), 377-392
https://www.scirp.org/journal/acs
ISSN Online: 2160-0422
ISSN Print: 2160-0414

Simple Qualitative Considerations for Understanding Radiation Balance and Global Environmental Temperature on Our Planet

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How to cite this paper: Vogelsberger, W. (2026) Simple Qualitative Considerations for Understanding Radiation Balance and Global Environmental Temperature on Our Planet. *Atmospheric and Climate Sciences*, **16**, 377-392.
https://doi.org/10.4236/acs.2026.162020

Received: February 24, 2026
Accepted: April 7, 2026
Published: April 10, 2026

Abstract

The increase in global environmental temperature is discussed in relation to basic laws of nature. Terms that are essential for the following considerations are compiled. The climate on earth is determined by the dynamic equilibrium. The energy supplied to the Earth by solar radiation must be completely radiated back into space. Energy inflow and energy output are in balance. The temperature regulates the maintenance of this dynamic equilibrium. The relation between supplied energy and temperature can be well described by a quadratic approximation function. Carbon dioxide as part of the atmosphere therefore is heated by the solar energy according to the principle of equipartition. Only one vibrational mode of carbon dioxide would be able to contribute to back radiation of the earth but it is frozen at room temperature. The temperature in carbon dioxide richer atmosphere is less increased by the same amount of energy. According to the first law of thermodynamics, energy used by humankind is not climate neutral if it causes a permanent change in our environment.

Keywords

Dynamic Equilibrium, Driving Force, Global Temperature, Carbon Dioxide, Equipartition Principle, Climate Neutrality

1. Introduction

In our time, an increase in global environmental temperature is being observed. It is referred to as climate change caused by human activity. The cause of climate change is seen in an increase in the carbon dioxide content of the atmosphere. Discussions and legislative proposals are therefore focusing on how the carbon dioxide content of the atmosphere can be regulated. An understanding of the scientific principles involved is necessary in order to evaluate these activities. It is not sufficient to rely on experts whose statements are generally accepted and therefore do not require verification. This approach can sometimes lead to decisions that contradict simple laws of nature and consequently fail to produce the desired results. The measures can involve large financial outlays that are ineffective and futile and, in times of tight budgets, waste public funds.

The natural processes that influence global environmental temperature are diverse and involve different branches of science, making it very difficult, if not impossible, to describe all influences correctly. It must therefore be pointed out that, due to the complexity of the processes that influence the Earth's climate, this essay contains qualitative statements that indicate fundamental trends and are based on basic laws of nature.

The sum of all energy in our environment cannot be influenced by humans. It is essentially constant, apart from extraterrestrial influences, such as fluctuations in solar energy. Human activity can only influence the distribution of total energy among different types of energy and utilize stored energy sources. Some mistakes in the use of energy and measures can be avoided if the scientific principles are understood and taken into account.

As a general rule, it is necessary to express opinions and judgements on matters only if one has the relevant expertise.

The aim of the following explanations is therefore to present the fundamentals of the processes that are relevant to global temperature in a way that is understandable even to people who are not primarily involved in the natural sciences.

The laws necessary for understanding are named after their discoverers, distinguished scientists (their names are printed in bold). These laws can be found in any relevant textbook on physics or physical chemistry. They cannot therefore be the subject of discussion. However, we would like to point out once again that this paper only provides a qualitative description of the facts. The basic law of dialectics formulated by **Georg Wilhelm Friedrich Hegel** on the transformation of quantity into quality, which should be remembered in many of today's discussions, plays an essential role in climate considerations.

Preliminary Remarks

The same facts are often interpreted differently in different contexts. One reason for this may be the point in time at which the assessment begins. This observation applies to any set of facts and therefore also plays an important role in the following considerations. Take, for example, a bouncing ball. If you only film the bounce, you can use the images to prove that objects move upwards on their own from the Earth's surface. One might say, "That's nonsense!" Everyone knows that the ball must first be thrown onto the ground. However, when assessing and classifying historical events, it is clear that the starting point and the shift in the starting point of the analysis can lead to different results. Therefore, when assessing scientific processes, it is also important to consider the point in time at which one begins one's observations and which factors one includes.

First, let's compile the terms that are essential for the following considerations.

2. Definitions

2.1. Temperature

The global environmental temperature plays a decisive role in climate considerations. However, it is obvious that a more precise definition is necessary for further discussion, because the temperature of the atmosphere changes with altitude in addition to the geographical longitude and latitude of the measuring point, and with depth in the ocean. Global surface temperature is used for the discussion of climate targets. It is an average value from measurements taken at various locations around the world at a height of 1 - 2 meters above the Earth's surface. It is therefore a temperature that is influenced by human activity.

2.2. Energy

The concept and application of energy are omnipresent in our society. It is generally taken for granted that nothing happens in our world without the expenditure or conversion of energy. However, in order to assess climate processes, it is necessary to take a closer look at the concept of energy. It has proven useful to divide energy into two basic types, namely heat and work. The effect of thermal energy is noticeable as a change in temperature; it is transferred by thermal radiation or thermal conduction. Work is used by humankind in particular in a wide variety of forms. Examples include mechanical, electrical and chemical work. The fundamental difference between the two types of energy is that when one form is converted into another, work can be completely converted into heat, whereas the complete conversion of heat into work is not possible. As we will see in more detail, climate and environmental temperature are determined by energy conversions. A special form of energy is potential energy. In this case, it is stored energy. It is not used at the moment of its creation and is stored in a form that allows it to be used at a later point in time. The storage of energy and its use at a later point in time plays a central role in considerations of global environmental temperature, as can be seen immediately when thinking about the use of fossil energy sources. It is also possible to use energy to bring about changes in our environment, as is the case in construction or transport, for example. Furthermore, the time at which energy is transferred is important for our considerations. Power (abbreviated here by the capital letter E) plays an essential role in climate considerations and is therefore used.

2.3. The Heat of Reaction

Chemical and physical changes in material systems are associated with the release or absorption of energy. We demonstrate this using a combustion reaction, as this type of reaction is particularly important for heating systems and thus for the temperature of our environment. A simple combustion reaction is the combustion of methane, a chemical compound whose molecules consist of one carbon atom and four hydrogen atoms, and which is the simplest representative of a very large group of chemical compounds, the hydrocarbons.

Methane + oxygen => carbon dioxide + water and combustion energy (heat)

It is clear that the combustion reaction of hydrocarbons produces carbon dioxide, water and heat energy (combustion heat). The amount of energy produced in such a reaction depends on the reacting substances. For the sake of completeness, it should be mentioned that different energy effects are generally possible during material transformations. For example, the conversion of water vapour into liquid water is of outstanding importance for the climate.

Water vapour <=> liquid water and condensation or evaporation energy

Energy is supplied during the condensation of water vapour. Energy is required for the evaporation of water. Both directions of this conversion are crucial for weather phenomena such as rain and drought, but are not discussed here. Separate considerations are necessary.

The relationship between heat energy, q, in general, *i.e.* including the heat of reaction, and temperature, T, is governed by the law formulated by **Gustav Robert Kirchhoff**.

$$dq = c_v dT \tag{1}$$

c_v is the heat capacity (heat absorption capacity) of the system under consideration. When considering the ambient temperature and climate, it should be noted that both heat and carbon dioxide are produced simultaneously during a combustion reaction. The decisive factors for a rise in temperature are how much initial product, in this case methane, is fed into the reaction and how quickly this is done.

2.4. Carbon Dioxide

Under conditions that normally prevail in our environment, carbon dioxide is a gas. It consists of molecules resulting from a linear arrangement of two oxygen atoms and one carbon atom, **Figure 1**.

Each molecule consists of an atomic nucleus surrounded by electrons electron shell. Each molecule has the ability to absorb and release energy in various forms. These forms of energy are different modes of motion: translational energy, whereby the molecule can move in all spatial directions; rotational energy, whereby the molecule can rotate around axes of rotation, symbolised by the green arrows in **Figure 1**; and vibrational energy, whereby the distances and angles between the three atoms change, symbolized by the red arrows in **Figure 1**. Furthermore, in the case of electron excitation energy, changes occur in the arrangement of the atomic nucleus and electron shell in the atoms, and changes are also possible in the atomic nucleus. These are used in nuclear power plants. However, both types of excitation are irrelevant to our further considerations and will therefore not be discussed. These considerations also apply, of course, to all molecules of different

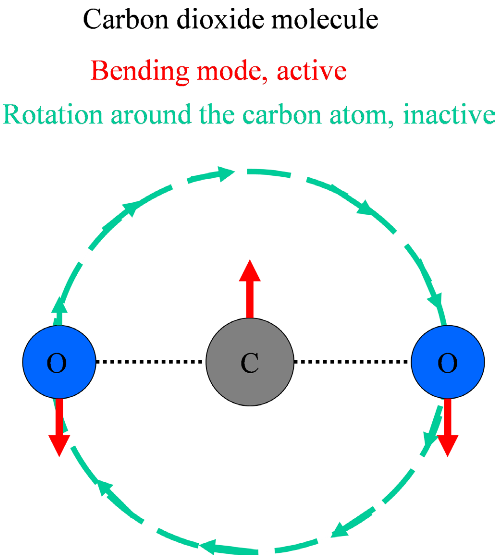

Figure 1. Schematic representation of a carbon dioxide molecule.

substances. Improvements of excitation possibilities for example centrifugal distortion or pressure broadening must be considered in quantitative calculations, but special knowledge is need for understanding of their influence. They are not discussed in the frame of this qualitative considerations, therefore. The specified forms of energy that a molecule absorbs or emits differ in the amount of energy required for these processes. In the above sequence, the amount of energy increases from kinetic energy to vibrational energy. The principle of equipartition of energy applies to translation, rotation and vibration. This means that at a certain temperature, each mode of motion (excitation possibility) absorbs the same amount of energy if the temperature is sufficient for this (equipartition theorem). Except for kinetic energy, the energies are quantized, *i.e.* they can only be absorbed or emitted in energy portions, quanta. Whether and how intensively the forms of energy can be excited can be determined by quantum mechanical investigations. For example, the vibration shown in **Figure 1** can be excited, but the rotation cannot. The energy of the radiation portions, quanta, that cause excitation or are emitted is determined by the wavelength (here abbreviated by the Greek letter λ) of the corresponding radiation. The shorter the wavelength, the greater the energy.

3. The Natural Cycle for Aerobic Life

Life on Earth is determined by a cycle driven by solar energy, **Figure 2**.

Plants use sunlight to convert carbon dioxide and water into chemical compounds such as carbohydrates (sugar, starch) and proteins, a large group of chemical compounds. These substances serve as food for humans and animals. They are burned in the body to produce carbon dioxide and water, releasing energy for life processes. The cycle is closed.

Without carbon dioxide, aerobic life is not possible.

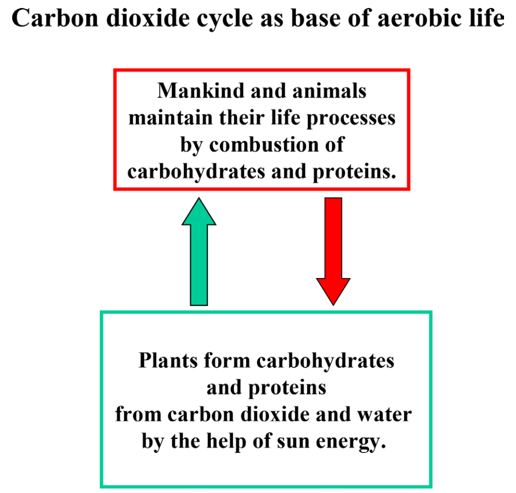

Figure 2. Schematic representation of carbon dioxide cycle.

4. The Influence of Heat and Carbon Dioxide on the Ambient Temperature

4.1. The Influence of Heat on Surface Temperature

The surface temperature on Earth is indicated daily on weather maps and illustrated by color coding. As we have seen, the global environmental temperature is an average value from various measuring stations, measured at a height of 1 to 2 meters above the Earth's surface. The influence of heat on temperature is obvious to everyone. Carbon dioxide is a reaction product of the combustion of organic matter and the metabolism of humans and animals, and is therefore linked to the energy turnover of these reactions. The reaction heat, which accounts for the largest share of the energy consumed by humankind, therefore has an influence on the ambient temperature. This can be estimated by a simple rough calculation, see Figure 3. The surface of the Earth is assumed to be the surface area of a sphere with the Earth's radius. On the surface is the layer of the atmosphere in which the temperature is measured, for example for television thermal imaging. Using humanity's annual energy consumption and the heat capacity of the ambient air,

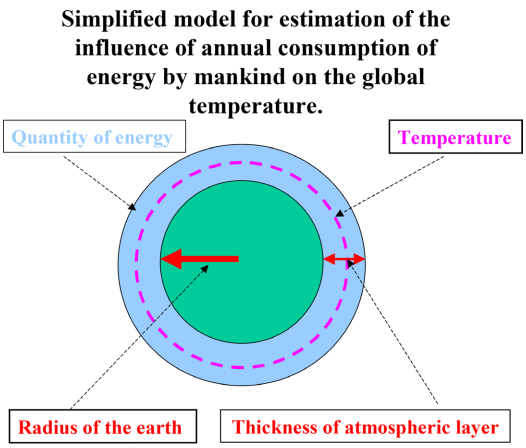

Figure 3. Schematic representation of the earth surrounded by an atmosphere.

it is possible to estimate the maximum annual temperature increase caused by humanity, which amounts to several degrees depending on the thickness of the atmospheric layer used. For example, the increase of temperature in a 100 m thick layer would be 10 K. Of course, this value could not be attained because of the existence of many nonequilibrium processes in the atmosphere. But it shows that this effect should be considered. It is therefore wrong to neglect this effect when calculating a possible increase in the ambient temperature. However, there is a second aspect to consider here, namely that, as we saw in the section on carbon dioxide, carbon dioxide can absorb and release energy. This ability is the basis for the possible involvement of CO_2 molecules in the Earth's energy balance. This issue is examined in more detail in the section on radiant energy.

4.2. The Influence of Radiant Energy on the Ambient Temperature

Most of the energy converted on Earth comes from the sun. Geothermal energy, the influence of the moon and radioactivity remain relatively constant over long periods of time. Their contribution to the Earth's energy balance is there-fore not considered separately. Solar energy is constantly radiated to the Earth. The angle of incidence of solar radiation relative to the Earth's surface must also be taken into account. If the amount of energy transferred in this way is to be specified, it must be related to a time interval (specification of power). Furthermore, the amount of energy that reaches the Earth also depends on the size of the area irradiated by the Sun. Therefore, the amount of energy, E, must also be related to a specific area size. The solar energy that reaches the edge of the atmosphere is therefore specified as the solar constant, E_0, power per unit area (W/m^2) ($E_0 = 1367$ W/m^2). However, this amount of solar energy is distributed across different types of radiation (e.g. ultraviolet, visible, heat and microwave radiation). The type of radiation can be characterized by its wavelength, λ. The proportion of solar energy accounted for by a specific wavelength, E_λ, is given by **Max Planck's radiation law**. It specifies the radiation intensity for all wavelengths of solar radiation. The frequency or wavelength distribution, $E_\nu d\nu = E_\lambda d\lambda$, of solar radiation on Earth is very well described by **Planck's law** of radiation and can be found in any physics or physical chemistry textbook, e.g. [1]. In the following discussion, the wavelength representation is used.

$$E_\lambda = \frac{2\pi hc^2}{\lambda^5}\left\{\frac{1}{Exp\left[\frac{hc}{k\lambda T}\right]-1}\right\} \tag{2}$$

h = **Planck's constant**, c = speed of light, k = **Boltzmann constant**, λ = wavelength of radiation, T = absolute temperature. The wavelength of the maximum radiation depends on the temperature in the radiation source, according to **Max Wien's displacement law**.

$$\lambda_{\max} = \frac{hc}{4.965\,kT} \tag{3}$$

Due to the protection provided by the atmosphere, significantly less radiant energy reaches the Earth's surface than is emitted by the Sun. The gas mixture in the air is heated by this process. **Figure 4** shows various radiation curves: the radiation from the sun that reaches the beginning of the atmosphere (red curve), the solar radiation that reaches the Earth's surface at an angle of incidence of approx. 42˚ (green curve), and the radiation emitted from the Earth into space (magenta curve). The curves show qualitative curves. The measured values are taken from various representations [2]-[4]. Precise measured values are available, for example, from ASTM reference spectra [5]. The black curve in **Figure 4**, calculated according to **Planck's law**, Equation (2), accurately reflects the course of the measured curves. It is modified by multiplying it by another constant so that the integral over all wavelengths gives the solar constant. A temperature of approx. 5800 K is used for the sun. For the radiation from the earth, the energy $E_0/4$ and a temperature of 288 K were used, Equation (2) (blue curve).

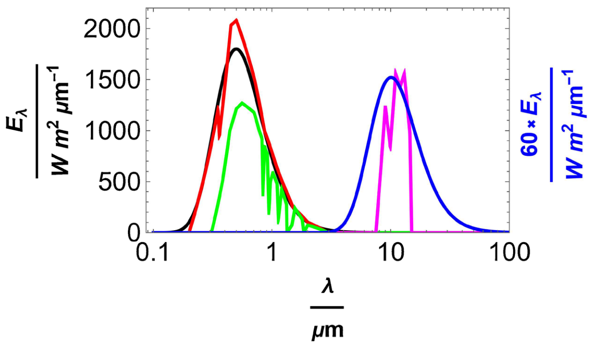

Figure 4. Logarithmic plot of different radiation curves.

The measurements show that decrease is particularly strong at certain wavelengths, **Figure 4**, green curve. The difference between the areas under the red and green curves indicates the portion of solar energy that is shielded by the atmosphere and therefore does not reach the Earth's surface. This is partly due to the described ability of molecules in the air to absorb energy from the sun and then radiate it in all directions, including back towards the sun. Carbon dioxide molecules in the atmosphere also have this ability, and water molecules have it to an even greater extent in the area of thermal radiation. In addition to kinetic energy, the molecules can absorb and emit vibrational energy and rotational energy in this area. They heat up to the ambient temperature. The deep spikes in the green curve are proof that, due to the effect of water and carbon dioxide molecules, less solar energy reaches the Earth than is available at the boundary of the atmosphere. The relevant effect of other components of the atmosphere is of course also present, but is not discussed here.

Both molecules therefore protect the Earth's surface from excessive heating.

The radiation arriving on Earth from the sun is completely reflected back into space by the Earth. A rough approximation calculates $E_0/4 = 342\ Wm^{-2}$.

Using Equation (2), the T-E value pairs for terrestrial radiation marked with red crosses in **Figure 5** were calculated in the temperature range 230 K ≤ T ≤ 350 K. (The integration was performed in the wavelength range 0.001 μm ≤ λ ≤ 1000 μm with a step size of 0.001 μm [6]). In **Figure 5**, the value pairs are shown as a function T(E). They can be well described by the quadratic approximation function, Equation (4) ($R^2 = 0.99998$).

$$T = 186.986 + 0.314 \cdot E - 0.000147 \cdot E^2 \tag{4}$$

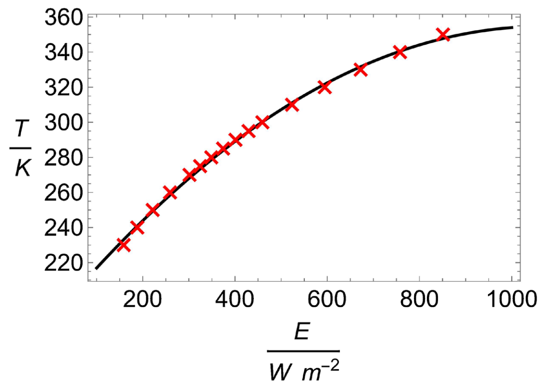

Figure 5. Temperature as function of radiated energy of the Earth.

To radiate the energy $E_0/4 = 342\ Wm^{-2}$, a temperature of 277 K is required according to Equation (4). The average temperature of the Earth's surface is given as approximately 15˚C, which corresponds to 288 K. However, this requires E = 395 Wm^{-2}. This difference is caused by the qualitative considerations used in this paper.

The Earth therefore acts as a **Planckian radiator** with temperature 288 K, **Figure 4**, blue curve. The measured intensity of radiation from the Earth is shown by the magenta curve in **Figure 4** [3]. Integration in the range 7 μm ≤ λ ≤ 15 μm yields an estimate of E = 66 Wm^{-2}. This value is far too small and therefore represents only a fraction of the Earth's radiation. Note that the intensity of Earth's radiation in the figure has been magnified a sixtyfold (60 × E_λ) to enable the presentation of the facts in a graph. In addition, a logarithmic scale is used for the wavelength in order to cover a larger wavelength range.

It can be seen that solar radiation is significantly weakened by interaction with molecules in the air in areas where Earth's radiation is negligible. Earth's radiation is only noticeable at longer wavelengths, but it should be noted that its intensity has been magnified sixtyfold. The intensity shown here is the radiation of the Earth. However, only the part of this radiation that is reflected back to Earth by the molecules in the air is effective for the greenhouse effect. A more detailed examination of the conditions shows that only the deformation vibration of carbon dioxide (**Figure 1**) could be excited. The molar heat capacity for an oscillation is given by Equation (5). Θ_{osc} is the characteristic oscillation temperature. For the bending mode, $\Theta_{osc} = 960$ K (R_G = gas constant).

$$C_V = R_G \left\{ \frac{(\Theta_{osc}/T)\,\mathrm{e}^{-(\Theta_{osc}/2T)}}{1-\mathrm{e}^{-(\Theta_{osc}/T)}} \right\}^2 \tag{5}$$

This mode and all other modes of motion of atmospheric gases can be excited by sun light ($T = 5800$ K). Besides radiation this energy is transformed into the other modes of motion especially translational modes (thermalisation). The heat capacity of the bending mode at $T = 288$ K is small, C_V (288 K) = 5.9×10^{-2} J·K^{-1}·m^{-3}. Its contribution to the heat capacity of the atmosphere is small, therefore.

At low temperatures, such as those found in the Earth's atmosphere, this excitation does not occur. The vibration is said to be frozen.

Earth radiation only affects the global temperature during the hours when there is no solar radiation. Since the temperature of the Earth's surface is higher than the temperature of the surrounding air during the night, a transfer of energy from the gas phase back to the Earth's surface is not possible according to the second law of thermodynamics. Back radiation of energy of excited bending mode of CO_2 in the direction of earth surface is small because of small excitation and thermal degradation. Its contribution to the global temperature is small, therefore.

Corresponding studies by **Knut Ångström** and one of his colleagues confirmed that there is no significant interaction between carbon dioxide molecules and terrestrial radiation in the sense of a greenhouse effect [7]. This statement does not apply to other components of the air, such as water in all states of aggregation.

The effectiveness of carbon dioxide as a greenhouse gas can be verified experimentally. It has been experimentally proven that CO_2 molecules are involved in protecting the Earth from the sun's heat radiation.

4.3. The Greenhouse Effect

The involvement of numerous processes in the warming of the Earth's atmosphere by solar radiation is referred to as the greenhouse effect. These processes include the excitation of energy states of molecules. Other phenomena are also cited in this regard. The effect of water droplets (clouds) is obvious and well known to everyone. But other small particles, such as soot, also play a role. The carbon dioxide in the atmosphere is publicly attributed with playing a special role in increasing the global environmental temperature. The magnitude of the CO_2 influence can be easily estimated. The gas mixture dry air, consisting of the main components nitrogen, oxygen, argon and carbon dioxide (volume fractions: 0.78084, 0.20942, 0.00934, 0.0004), is heated during this process. The absorbed energy is distributed to the modes of motion in accordance with the equipartition theorem in order to achieve the global ambient temperature. The gases absorb heat in accordance with their heat capacity. At a temperature of 25˚C, the heat capacity of carbon dioxide is significantly greater than that of the other components of air ($C_V(N_2)$ = 20.74 J/K mol, $C_V(O_2)$ = 20.95 J/K mol, $C_V(Ar)$= 12.48 J/K mol, $C_V(CO_2)$ = 28.46 J/K mol). If the proportion of CO_2 is increased at the expense of the other components of air, the same amount of heat causes a smaller temperature increase in the case of increased CO_2 concentration, according to Equation (1). In an atmosphere richer in CO_2, the temperature rises less sharply as a result of solar radiation. The effect is very small (µK range) due to the low CO_2 concentration. However, it contradicts the view that an increase in the concentration of CO_2 in the air raises the global environmental temperature.

5. The Influence of Energy Flows on Climatic Conditions

5.1. Dynamic Equilibrium

The energy supplied to the Earth by solar radiation must be completely radiated back into space. Energy inflow and energy output are in balance. This state is referred to as dynamic equilibrium. It is shown schematically and in a very simplified form in **Figure 6**.

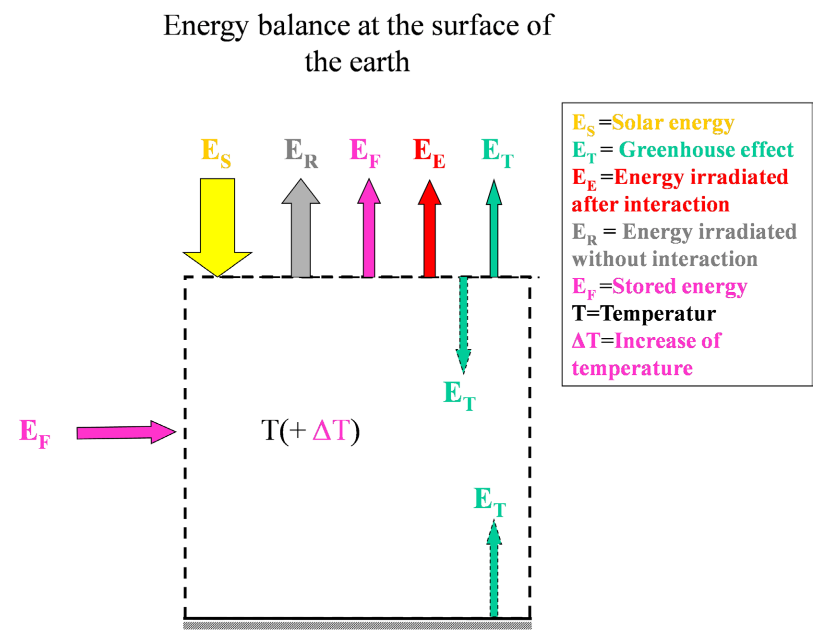

Figure 6. Schematic representation of energy balance in a volume near to the surface of the earth.

The temperature regulates the maintenance of this dynamic equilibrium. Temperature is the driving force behind energy radiation. This statement is formulated in **Planck's law** of radiation. If more energy is supplied to the Earth system, the ambient temperature rises until equilibrium is restored, see Equation (4) and **Figure 5**. This statement is of course also valid if energy is supplied to the Earth system from another source. One such source is fossil fuels. Their energy is released into the surface layer of the atmosphere where, as we have seen, the global environmental temperature is measured. Fossil fuels store the solar energy of past periods, and this energy is released into the environment in our time. The result is a corresponding rise in temperature. Saving fossil fuels therefore contributes to preventing a further rise in the environmental temperature.

The use of renewable energies is seen as a solution to the problem of energy demand. When fossil fuels are depleted in the distant future, it would still be possible to provide the necessary energy in this way.

But what about the claim that the use of renewable energy is climate neutral?

Climate neutrality used within this considerations means that the use of an excess of energy has the same effect on global temperature as if it is transferred directly as heat in the dynamic equilibrium. Storage of energy likewise in electrical batteries shifts the influence of this energy on global temperature to a later date.

The energy arriving on Earth from the sun can be divided into the two parts shown in **Figure 6**: the energy that is immediately reflected back into space without interacting with the Earth (grey arrow) and the energy that interacts with our environment in some way and is therefore responsible for the rise in environmental temperature (red and green arrows). If the energy symbolized by the red arrow is used for human needs, e.g. to perform work, on its way to being radiated, the effects on the environmental temperature must be carefully examined in terms of climate neutrality. However, if energy that is radiated back without interacting with the environment is used to perform work (grey arrow), additional energy is supplied to the environmental system and the temperature rises. The grey arrow becomes smaller and the red arrow becomes larger by the same amount. The same applies to the use of renewable energy, magenta arrow. Energy use is not climate neutral.

5.2. Climate Neutrality

As we have seen, before claiming that energy use is climate neutral, a thorough examination is necessary. A distinction must be made between thermal energy and work. In principle, work is not climate neutral if it causes a permanent change in our environment. The energy is stored in the environmental change and is no longer available for maintaining the dynamic equilibrium in our environment (potential energy). For example, electrical energy is used in transport to change the location of objects; it is consumed, or the energy required to construct a building remains stored in that building. This statement also applies, of course, to the use of renewable energies.

The following general consideration illustrated in **Figure 7** shows that a precise analysis is necessary. We discuss the simple case where, at the initial state of our considerations, a system is in a state, S_A, with a higher energy than its environment. This is the case, for example, in the generation of energy from wind energy. For simplicity, we consider air to be an ideal gas with a constant molar volume V = 1 $m^3 \cdot mol^{-1}$ and a pressure p_S that is significantly higher than the atmospheric pressure p_G ($p_S > p_G$). According to the equation of state for ideal gases, the temperature T_S is fixed ($T_S = p_S \cdot V/R_G$). The increased energy content is characterized by the temperature, T_S, which is higher than the average ambient temperature, $T_G = p_G \cdot V/R_G$ ($T_S > T_G$). The total energy, u, consists of two components: heat, q, and work, w. If no action is taken, the system enters a state of dynamic equilibrium, S_G, by releasing the total energy difference ($\Delta u = u_S - u_G$) as heat, q, (red arrow, path A).

$$\Delta u = u_S - u_G = q = C_V (T_S - T_G) \tag{6}$$

(C_V = molar heat capacity of air).

On a second path B, part of the heat is used to perform work, w, $q = q' + w$ (green arrows). The system transitions to state S_M, which is characterised by the variables T_M and p_M ($T_S > T_M > T_G$).

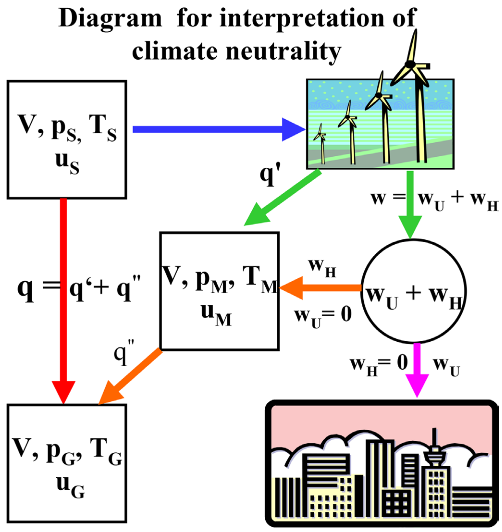

Figure 7. Schematic representation of energy transfer according to the first law of Thermodynamics.

The work, w, for example electrical work, can be used for heating, w_H = q" (ochre arrows). The system ends up in the state with the ambient temperature, T_G. This is the same state as that reached on path A if energy losses are excluded during conversions (ideal case) and the work w_H has only been used for heating purposes. If, on the other hand, the energy w_U is used for changes in the environment, for example in transport or the construction industry, the state S_G cannot be reached (magenta arrow). Only the lower heat q' is released. The system remains at the temperature T_M ($T_M > T_G$). A temperature increase occurs. The statement that the use of increased energy for work to bring about changes in the environment, e.g. transport or construction, leads to an increase in the global temperature in the system under consideration compared to the case where no work is done from the initial energy difference, is generally valid. The use of renewable energy is not climate-neutral.

In the case of a photovoltaic system, a second aspect must be taken into account. When idle, the system is in thermal equilibrium with its environment. The interaction with the environment consists mainly of temperature equalisation. When in operation, the thermal equilibrium continues to exist. In addition, however, solar energy that was previously unused is used to generate electricity. In this case, climate neutrality does not apply.

However, there is another point to consider when assessing climate neutrality.

When renewable energy is stored, it is missing from the dynamic equilibrium at the time of generation. However, this loss can be instantly compensated for by solar energy, which is available in large quantities. The dynamic equilibrium is not affected by the stored energy. When used later, the stored energy increases the energy supply and the temperature rises. The speed at which the energy is supplied must also be taken into account. Dynamic equilibrium is established in such a way that the amount of energy supplied and released per unit of time is equal. Climate neutrality is only achieved in this case. When using renewable energies, it must be carefully examined whether their use is actually climate neutral. This examination can be time-consuming in individual cases.

6. Summary

Statements on any issue always require a sound knowledge of the facts. They must also always allow for the possibility of correcting one's personal position if one realises that one has overlooked an aspect.

The considerations presented here confirm that questions concerning changes in environmental temperature affect a very complex system and are therefore difficult, if not impossible, to answer quantitatively. However, a qualitative statement is possible if sound scientific knowledge of the fundamentals of physics and chemistry is used. The aim of the present considerations is to enable such an approach.

They have shown

- that without carbon dioxide, aerobic life is not possible.
- that thermal energy associated with chemical reactions must be taken into account when considering changes in environmental temperature.
- carbon dioxide is produced during the combustion reactions of organic substances. It is therefore involved in heat generation.
- that carbon dioxide gas molecules in the atmosphere are involved in shielding the Earth from heat radiation. Like the other components of the atmosphere, carbon dioxide contributes proportionally to the warming of the atmosphere.
- that the contribution of carbon dioxide gas molecules in the atmosphere to the greenhouse effect is negligible.
- that energy use that causes a permanent change in the environment is fundamentally not climate neutral.
- that climate neutrality in the sense that the use of renewable energies has no influence on the ambient temperature does not generally exist. When renewable energies are used for heating purposes, only a minor influence on the ambient temperature is to be expected compared to the natural decomposition of the energy surplus. If renewable energies cause permanent changes in the environment, the temperature in the area under consideration will rise.
- that the energy radiated by the sun onto the Earth and the energy radiated by the Earth into space are in dynamic equilibrium, *i.e.* their energy amounts are equal.
- that the driving force for the Earth's energy radiation is the global temperature.
- An additional supply of energy to the Earth causes a rise in temperature, which

increases the driving force for radiation.

- that in a dynamic equilibrium, the speed at which radiation and emission occur also plays a role. The decisive factor is that the amount of energy received and emitted in a given period of time is the same.
- that stored energy is not lacking in dynamic equilibrium, as it can be instantly replaced by the large surplus of incoming solar energy. Dynamic equilibrium is not influenced by stored forms of energy.
- that stored energy increases the ambient temperature when it is used.
- that a reduction in green spaces on Earth can cause an excess of carbon dioxide to build up in the aerobic life cycle.
- that the effects contributing to global environmental temperature change must be experimentally verified before proceeding with large-scale implementation to prevent a rise in temperature.

Reducing humanity's energy consumption is the only means of effectively limiting or preventing the rise in environmental temperature. Reducing the carbon dioxide content in the atmosphere reduces the atmosphere's shielding effect in terms of solar heat radiation. The rise in environmental temperature is increased. The contribution to the greenhouse effect is negligible.

7. Final Remark

Without carbon dioxide, aerobic life on Earth would not be possible. Carbon dioxide is present in the atmosphere in low concentrations. Experiments have shown that it contributes to shielding the Earth from solar radiation in the form of heat radiation. In doing so, it contributes to the warming of the atmosphere. Carbon dioxide does not play a significant role in the greenhouse effect. Experiments conducted at the beginning of the last century confirm this statement. The amount of energy consumed by humanity each year is sufficient to cause a temperature increase of several degrees in the layer of the atmosphere closest to the Earth, as shown in weather reports. This is the main contributor to global warming. Any use of energy that causes a lasting change in the environment is fundamentally not climate neutral. Renewable energies are not necessarily climate neutral. This must be verified experimentally and will only be true in rare cases. Experiments suggest that a certain increase in environmental temperature is attributable to human activities. This has also been proven to apply to environmental damage to plants and animals, which can even lead to the extinction of species. It is to be hoped that this devastating development can still be reversed. To do so, humanity must change its future development and its self-image. It is an equal part of our living environment. It has the ability to foresee the consequences of its actions. Therefore, it is not its task to constantly increase and satisfy its own needs, but rather it has a duty to shape its needs in such a way that the needs of other individuals on Earth are also taken into account and that a contribution is made to the preservation of creation.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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