



A Novel Model to Assess the Earth's Greenhouse Effect

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Abstract: The “greenhouse effect” is the warming of the Earth's surface due to the presence of “greenhouse gases” in the atmosphere. It is said to be 33 °C (“natural greenhouse effect”) and rising with greenhouse gas concentration (“additional” or “anthropogenic greenhouse effect”). But its height, and even its very existence, are controversial. For example, some people claim that it cannot exist because it cannot be measured, others claim it violates the second law of thermodynamics, and again others argue that, even if the effect exists at all, it cannot increase with concentration because the absorption is already saturated. As a constructive contribution to the discussion, a novel model is presented here which can not only help to clarify the existence of the effect but also allows us to estimate its size from well-known measurements.

This model consists of a row of bodies, the first one constantly heated, the last one constantly cooled, those between freely adjusting their temperatures through radiation from their neighbors. When an additional body is inserted into that row, a temperature spread develops in it, so that the body in front of the new one must warm up by half of this spread and that behind it must cool down accordingly.

Applying this model to the real Earth, the temperature of the Earth's surface is warmer with greenhouse gases in the atmosphere than without by half of the temperature spread between the lower and the upper part of the atmosphere. This vertical temperature spread is well-known, it only has not been interpreted in this way hitherto. The agreement with the “natural greenhouse effect” of 33 °C, calculated by complex climate models, is surprisingly good. The model also allows to better refute some of the usual counterarguments against the greenhouse effect. Its weakness is that it is too coarse to make a statement about the increase of the greenhouse effect when the CO₂ concentration is enhanced (“additional greenhouse effect”). Lessons learned, limitations, related problems, and open questions are discussed.

Key words: Back radiation, carbon cycle, climate model, CO₂-concentration, global warming, greenhouse effect, greenhouse gases, latent heat removal effect, saturation of absorption, Second Law of Thermodynamics.

1. Introduction

Let's start with the definition of a few terms, as they are used in this paper, to avoid misunderstandings:

- The “greenhouse effect” is the (actual or postulated) warming of the Earth's surface due to the presence of “greenhouse gases” in the atmosphere. A distinction is made between the “natural greenhouse effect”, which is the warming that already had been there before humankind started the industrial revolution, and the “additional (or “anthropogenic”) greenhouse effect”, which is the increase of the effect due to increased concentration of “greenhouse gases” in the atmosphere, which most people assume to be man-made.
- “Greenhouse gases” are gases that are essentially transparent for the visible light from the sun but absorb a substantial portion of the IR-radiation emitted from the Earth's surface. According to its absorption bands, CO₂ definitely is such a “greenhouse gas”. Others are water vapor, methane, and some more.

- “Back radiation” is any radiation that exists as a result of IR-radiation from the Earth's surface, and that is directed to the Earth's surface by whatever process. The process that causes this “back radiation” in the greenhouse effect is described in section 2.1.

The “greenhouse effect” has been controversial ever since it was postulated. There seem to be good arguments in favor of it, but apparently, they are not good enough to convince sceptics. An end to the debate is not in sight. In this paper, some important issues in this debate are briefly described (section 2) to then propose a novel model as a remedy for the deadlocked debate (section 3), including discussion of constraints, limitations and open questions (section 4). Summary and conclusions complete the paper (section 5).

2. Starting position: The deadlocked debate

2.1. Classical description of the greenhouse effect

The sun warms the Earth. The Earth's surface adapts itself to that temperature at which it radiates the same amount of energy per second into space as it receives from the sun (balanced radiation balance). According to Stefan-Boltzmann's law, this temperature should be 255 K (= -18 °C) (solar constant 1364 W/m², 30 % albedo). But what we measure is about 288 K (= +15 °C). The difference of 33 °C is called the “natural greenhouse effect”. It comes about because water vapor, CO₂, and some others (“greenhouse gases”), which are naturally present in the Earth's atmosphere, are largely transparent to incoming sunlight but absorb a large portion of the IR radiation emitted by the Earth's surface.

But absorption is not all: Physics (Kirchhoff's law of radiation) tells us that every body that absorbs radiation also emits radiation, the same amount as it absorbs, only in all directions. This also applies to greenhouse gases in the atmosphere. They absorb radiation, and they radiate half of the energy they have absorbed out into space, and the other half down to the Earth's surface (“back radiation”). The Earth absorbs at least part of this back radiation, what means energy supply to the Earth, in addition to the energy it gets directly from the sun. Both energy flows together heat up the Earth's surface to higher temperatures than the direct radiation from the sun alone, that's the greenhouse effect (see [1-4]). This warming continues until the radiation balance is restored. Even if the exact value is disputed, there is no doubt that it is this warming of about 33 °C that makes the Earth habitable, we should be thankful for it. But when the atmospheric concentration of CO₂ rises, the warming span rises too. And it is this “additional” or “anthropogenic greenhouse effect” which many researchers believe could seriously endanger life on Earth by excessive warming. But others believe that this additional warming is rather minimal, some even see the possibility of an overall cooling effect. There's still a lot of open questions here.

2.2. Classical counterarguments against the greenhouse effect

Three frequently raised counterarguments shall be discussed in more detail in this paper:

1. Non-measurability: Even though there are already very good experiments to prove the existence of the greenhouse effect (e.g. [5]), some people still claim that all such experiments have failed. Therefore, they argue, it is not permitted to base far-reaching decisions on this unproven effect. Others even claim that something that cannot be measured does not exist at all.
2. Contradiction to the Second Law of Thermodynamics: Some people say that warming of the warm Earth by the cold atmosphere would give a perpetuum mobile, what is prohibited by the said law. This law stipulates that heat can flow spontaneously only from warm to cold, never in the opposite direction. Consequently, these people say, back radiation, if it exists at all, can perhaps slow down cooling of a warm body, but never can warm a warm body. Therefore, these people say, the greenhouse effect cannot exist in principle.
3. Saturated absorption: The absorption of IR-radiation by CO₂ in the atmosphere is already saturated, more than 100 % cannot be absorbed. Therefore, additional CO₂ cannot generate additional warming, some people say.

2.3. Classical rejections of these counterarguments

None of these counterarguments are new, all have already been rejected a thousand times:

1. Lack of experimental evidence: In literature, many experiments can be found that allegedly prove (e.g. [5] or [6]) or disprove (e.g. [7]) the existence of the greenhouse effect. All these experiments are controversial, with the respective opposing side disputing their validity. Be that as it may, even if someone accepts that all attempts to prove the greenhouse effect experimentally have failed so far, it is definitely not allowed to draw the conclusion from this that the effect in question does not exist. Perhaps, there have just not been the right experiments carried out, or at least not with sufficient sensitivity. There are many physical effects, whose experimental proof has been possible only many years after their postulation, but of course these effects already have existed before that proof. In short: A lack of experimental proof is never a valid argument against the existence of any effect!
2. Second Law of Thermodynamics: The above-mentioned argument with a prohibited perpetuum mobile is based on a doubly false understanding of this law: First, this law does not prohibit heat transfer from cold to warm, it only requires that more heat is transferred from warm to cold at the same time. In other words: The Second Law only regulates the net transfer of heat. Principally, every body emits radiation according to its temperature, and when two bodies irradiate each other, each one transfers heat to the other, from warm to cold and also vice versa. The Second Law only determines the sign of the difference. And whenever a body hit by radiation absorbs at least a part of that radiation, this means heat supply to that body (conservation of energy!).
 Second, if one takes a closer look, this law states that a colder body never can warm a warmer body spontaneously ("of itself"). That means, it cannot do it within an isolated system. But neither the atmosphere alone nor the Earth and the atmosphere together are an isolated system. Rather, they continuously get energy from the sun. The warming of the Earth's surface does not happen "of itself", but through a continuous supply of energy from the sun, in the case of greenhouse gases in the atmosphere strengthened by back radiation from these gases. Therefore, the Second Law does not prohibit the greenhouse effect. This effect only shifts the temperature of the boundary between the Earth's surface and the atmosphere to a higher value, without reversing the direction of the net heat transfer (which always goes from the sun to the Earth, from the Earth to the atmosphere, from the atmosphere into space).
 The second part of this argument was slowing down of cooling instead of warming: This line of argumentation is inadmissible from its basic approach: If back radiation has any effect on a body hit by it, this effect cannot vanish just because the body hit got its actual temperature as equilibrium between heating and cooling instead of as cooling down from higher temperatures. There is only one difference: When the body hit got its temperature by cooling, the energy added through absorption of back radiation slows down that cooling if the added energy is small, and if it is large, it changes the overall effect into warming. But when there is equilibrium as the starting point, even the smallest addition of energy causes warming.
 One more thought on that: The Earth together with its atmosphere is the body between sun and space. Replace it with a two-layer structure. The interface between the two layers has a certain temperature. Now reduce the thermal conductivity of the outer (and cooler!) layer: The temperature of the interface will rise. The warming of the Earth's surface by greenhouse gases in the atmosphere is not much different.
3. Saturation of absorption: Greenhouse gases in the atmosphere absorb IR-radiation at well-defined absorption bands. In these areas, all IR-radiation from the Earth's surface is already absorbed, more absorption is not possible. Insofar, the argument of saturation is correct. But that does not hold for the flanks: Even if they are steep, they are not infinitely steep. An increased concentration inevitably means more absorption in the flanks. It is this increased absorption that brings about the additional warming of the Earth when the concentration rises.

2.4. Interim result

All three counterarguments discussed here have already been rejected many times (section 2.3.), there should not be any doubt on the existence of the greenhouse effect. But that doesn't help, the same arguments are put forward again and again, undeterred. As a possible remedy to this deadlocked debate, a novel model is presented in section 3, which perhaps makes it a little bit easier to find the correct understanding of how the greenhouse effect works, and which also allows us to estimate its size from well-known measurements.

3. Possible remedy: The model

3.1. Thought experiment

In view of the statements made above, the existence of the greenhouse effect should be undisputed, but the debate is going on and on. And regarding the size of the effect, the lack of measurements is a problem in any case. Without measurement, a quantity can never be specified precisely. As a remedy, let us try a thought experiment: Take a row of bodies, all of the same size, for example four bodies, one behind the other, separated by small gaps, as sketched in Fig. 1, upper line. The first body is heated to temperature T_h (h for hot), the last one is cooled to temperature T_c (c for cold). Aside from that, each body only receives energy through radiation from its neighbors. In equilibrium, the temperatures from left to right form a sequence of steadily decreasing numbers ($T_h > T_1 > T_2 > T_3 > T_4 > T_c$).

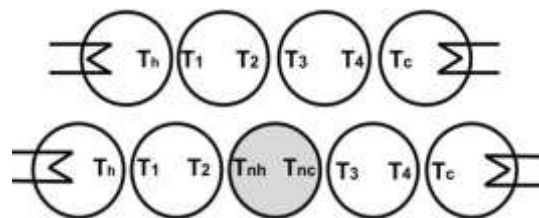


Figure 1: **Bodies in a row.**

The first one is heated to a constant value, T_h , the last one is cooled to a constant value, T_c . The other bodies adjust their temperatures in equilibrium of heating and cooling. Upper line: Four bodies as an example. Lower line: One more body, inserted in the middle of the row, grayed out to highlight it. It develops a temperature spread ($T_{nh} - T_{nc}$). The body in front of it (T_2) warms up by about half of this spread, and the body behind it (T_3) cools down by the same amount.

Now we add a fifth body in the middle of the row (Fig. 1, lower line). Starting cold, it warms up by radiation from its neighbors, more on its left side than on its right side. In equilibrium, it shows a temperature spread of ($T_{nh} - T_{nc}$) (n for "new body"). Since the total temperature difference ($T_h - T_c$) has remained unchanged, the body in front of the new one must have warmed up, and that behind it must have cooled down. For small gaps between the bodies, the temperature drop mainly occurs inside the bodies, so that the cold side of the body before, T_2 , has increased by about half of the temperature spread within the new body ($T_{nh} - T_{nc}$). To put it bluntly: The body in the row in front of the new one *has warmed up as a result of adding a cooler body* (in cooperation with the continuous heating of the first body, whose temperature is kept constant)! The temperature of this body before (T_2) rose by about half of the temperature spread in the new body. That's exactly analogous to how the greenhouse effect works. With this novel model, we can understand it better.

4. Discussion

4.1. Lessons learned

What can we learn from this novel model for the real world? In the latter, if we ignore the atmosphere for a moment, we have a row of three bodies: Sun, Earth, and space. The first two are spheres, the third is a hollow sphere, surrounding the other two. Hence, the middle body, the Earth, is reduced to its surface, which exchanges radiation with the sun and with space (note: the mass of the Earth does not matter here, as long as we only look at equilibrium conditions). And if we add the atmosphere (including its greenhouse gases) as an additional body, it is essentially transparent for sunlight but absorbs a crucial portion of the Earth's IR-radiation. Therefore, the correct place for the new body in the row of bodies is between the Earth's surface and space. And due to its

direct contact with the Earth's surface, its warm temperature, T_{nh} , is practically the same as that of the Earth's surface ($288\text{ K} = +15\text{ }^{\circ}\text{C}$). And its cold temperature, T_{nc} , is that of the upper part of the dense atmosphere (about 10 to 15 km height), from where radiation (from CO_2 and from other greenhouse gases) is emitted directly into space. This temperature varies depending on location and season but is roughly in the range of about $-50\text{ }^{\circ}\text{C}$ to $-80\text{ }^{\circ}\text{C}$. Therefore, the addition of the atmosphere warms the Earth's surface by about $40\text{ }^{\circ}\text{C}$ (half of the vertical spread in the atmosphere)! This is not speculation, nor is it calculated by sophisticated formulas on the basis of uncertain assumptions, it is simply a measurement that has long been available. The only new thing is that with due regard to the novel model this measurement gives valuable information on the greenhouse effect.

But before we discuss the size of the greenhouse effect in more detail, let's have another look at the counterarguments reviewed in section 2, now with all the information we have available from this novel model:

- Counterarguments 1 and 2 (lack of experimental evidence, and contradiction to Second Law) collapse, because there is an easy-to-perform experiment that unambiguously proves that, under appropriate boundary conditions, a cold body can warm a warmer one. The appropriate boundary conditions are ongoing energy supply from an external source. In the case of the novel model, the external energy source is the heating of the first body, and in case of the greenhouse effect, this external energy source is the sun. It delivers energy to the Earth with and without greenhouse gases.

One more note on running the experiment: If the hot temperature, T_h , is chosen high enough, it is not even necessary to use a vacuum to show the warming of a warm body by a cold one unambiguously. Anyone can check it easily for themselves.

- Counterargument 3 (saturation of absorption) is not directly affected by the model but gives reason to point to a special feature of the greenhouse effect: This effect works with IR-radiation, not with light. If a light photon is absorbed, it vanishes. Therefore, if the Earth's atmosphere would absorb all the light emitted from the Earth's surface (for example by clouds), the Earth would look completely dark from the outside (except for sunlight reflected by the atmosphere). Not so for IR-radiation: If an IR-photon is absorbed in a greenhouse gas molecule, a new photon of the same energy is emitted from that molecule a short time later (whereby it is irrelevant, whether the molecule had retained its excitation energy in the meantime, or had temporarily released it through collisions with other molecules and had been re-excited by other collisions). As there is no preferred direction for the photons emitted in this way, half of them go towards the Earth and the other half go outwards towards space. Therefore, absorption of 100 % of the IR-photons emitted from the Earth's surface within the atmosphere does not mean "no radiation outside the atmosphere". Rather, outside there is half as much radiation. And if the atmosphere is thicker (if it contains more CO_2), then this radiation, directed to the outside, is still inside the atmosphere; therefore, it too is absorbed on its way out, and new radiation is emitted in its place, equal in all directions again. This continues until half as much radiation actually goes out into space, as is emitted from the Earth's surface (the other half goes back to the Earth's surface). We can also state how much this is: As the Earth must always be close to equilibrium, about the same amount of radiation must go out into space as the Earth receives from the sun. Therefore, the amount of radiation emitted from the Earth's surface is twice as large as the radiation the Earth's surface gets from the sun. The Earth just warms up to that temperature, where this radiation balance is reached. For clarification: That's just another description of the greenhouse effect.

To be precise: This description is only valid for those wavelength areas in which greenhouse gases actually absorb. Parallel to this, outside these wavelength areas, a portion of the Earth's IR-radiation goes unhindered through the "atmospheric window" directly into space. It is the sum of these two paths that equals the amount of energy the Earth absorbs from the sun.

The bottom-line of all this is that the Earth's atmosphere is never a barrier to IR-radiation. Rather, the same amount of IR-radiation is always pushed through the atmosphere into space (one portion through multiple absorption and re-emission, the other portion directly through the atmospheric window). And since a higher CO_2 concentration means a greater resistance to this push-through, the Earth's surface

must warm up when the CO₂ concentration increases. Saturation of absorption does not constitute a limit. That's the difference between IR-radiation and light.

Supplemental remark: The novel model also only works with IR-radiation, not with light. If the first body in the row were illuminated with light on its left half instead of being heated by a heating coil, the new body in the middle of the row would be in the shadow, not getting any light. Transfer of energy in the row of bodies is only carried out by heat radiation (IR-radiation), not by light radiation.

4.2. More to the size of the effect - Limitations

As already said, the Earth's surface warms up by about half of the vertical temperature spread in the atmosphere, when the atmosphere including greenhouse gases is added as a new body. But on a closer look, this warming up is not just due to back radiation from greenhouse gases, rather it is the answer created by all changes caused by adding the atmosphere, including formation of oceans (there are none without an atmosphere!), distribution of heat by mechanical currents in air and water, vaporization, cloud formation, and so on. The share contributed by back radiation cannot be determined in this way, but it definitely is substantial. And again, the overall value of about 33 °C for the "natural greenhouse effect" is surprisingly well confirmed.

This is decisively different with the "anthropogenic (or "additional") greenhouse effect": To simulate this effect with the novel model, it would be necessary to change the thermal conductivity of the new body in the row. Of course, this would be easily possible, just change the material, but it is difficult to determine by how much the thermal conductivity should be changed to simulate the "additional greenhouse effect". And, since this effect is much smaller, inaccuracies, and possibly also other effects involved, play a much larger role. Therefore, quantitative statements are not possible in this way. As an example for such other "possible effects", the "latent heat removal effect" shall be discussed in some detail.

4.3. Latent heat removal effect

Once again: Energy is radiated from the Earth's surface towards space. A part of it is absorbed on its way out in greenhouse gases in the atmosphere, bringing energy into the atmosphere. This energy is then re-emitted in all directions, meaning 50 % out into space, and 50 % towards the Earth. These 50 % warm the Earth's surface in addition to the radiation directly from the sun. This is the "greenhouse effect".

But this process is not the only process that transfers heat from the Earth's surface into the atmosphere: This is also achieved by conduction, by convection, and, above all, by vaporization (latent heat). We always have this additional import of heat into the atmosphere (additional to the import via radiation), but without greenhouse gases there would be no emission of radiation from the atmosphere, and therefore, none of the heat imported into the atmosphere by these processes would dissipate into space. All of it would only be delivered back to the Earth's surface via material-bound processes like conduction, convection, rain or hail. However, with greenhouse gases, a part of this heat imported into the atmosphere is radiated into space. In other words: Whenever greenhouse gases exist in the atmosphere, they not only bring about the "greenhouse effect", but rather also *open up a second path* to transport heat from the Earth's surface into space. The first section of this second path, from the Earth's surface into the atmosphere, is conduction, convection and latent heat, the second section, from the atmosphere into space, is radiation. In the scientific literature, this second path is of course described, but I have not found a name for it. In [8] I just named it after its largest contribution "Latent Wärme Abfuhr Effekt" (German, in English: "latent heat removal effect"). A name doesn't change anything in substance, but it makes discussions easier.

It is important to realize that we can only have the two effects together: The "greenhouse effect" as warming via back-radiation, *and* the "latent heat removal effect" as cooling via additional heat dissipation into space. We know that, at low concentrations, the "greenhouse effect" is much stronger than its counterpart, we know this because of the large "natural greenhouse effect". But when the concentration rises, saturation effects of the absorption of radiation should gain weight. Although 100 % absorption is not a limitation (see above), above that value the transport of energy through the atmosphere encounters more resistance in any case. An analogous weakening does not exist for the "latent heat removal effect" (practically unlimited availability of water to be evaporated!). Therefore, these two effects should balance each other out at a certain concentration. Above that

concentration, the “latent heat removal effect” should even predominate, resulting in an overall cooling by additional greenhouse gases. Today, probably no one can say for sure where this transition point is. With regard to the “natural greenhouse effect”, this is irrelevant, this effect implies in any way a strong warming, as already stated in the order of 33 °C. But regarding the much smaller “additional greenhouse effect” (at most a few degrees), this counter-dependency with unknown point of intersection prevents a reliable statement regarding its size (and even its sign).

In short: “Bodies arranged in a row” do prove the “natural greenhouse effect”. However, it is an inappropriate model to evaluate the existence and the size of the “additional greenhouse effect”.

4.4. *Supplementary remarks*

The model with “bodies arranged in a row” and the other considerations above seem to resolve two issues finally: First, the “natural greenhouse effect” exists, and it is really this effect that warms the Earth to habitable values. We should be happy about its existence. And second, additional CO₂ causes additional warming, but it also inevitably causes cooling simultaneously. Soberly, there is great uncertainty as to which effect predominates under which conditions.

So far, so good, but if we cannot quantify the effects of additional CO₂, it is all the more necessary to think more fundamentally about this CO₂. One question arises in particular: What is the real cause of the growth in concentration?

Rationale: As shown above, if you put together all effects, more CO₂ in the atmosphere *may* warm the Earth additionally (“additional greenhouse effect”). The significance of this “may” – as opposed to “cannot” – is a consequence of the widespread fear of climate catastrophes caused by human CO₂ emissions: “Cannot” rules out such disasters, “may” makes them possible in principle. So, this “may” is the basis for the frequently raised request to stop our emissions of CO₂ completely as soon as possible. However, even if the net effect of additional CO₂ in the atmosphere really were warming (for some of the uncertainties see above), even if it were substantial warming (that’s what most computer models predict), the specified request can only be justified in principle if *one prerequisite is fulfilled*: The increase in the atmospheric concentration of CO₂ must be predominantly manmade. Otherwise, if not predominantly manmade, any possible resulting warming, however big it may be, is mainly a natural effect about which we can do nothing except prepare for possible consequences. This seems to be simply dictated by logic.

Thus, „manmade or not” is the question! Most experts see it as proven: The increase in the concentration of CO₂ is manmade. We have emitted twice as much CO₂ as has accumulated in the atmosphere, and therefore, human emissions are the cause of the increase in concentration, there is no room for other sources, it is said (for example [3] and [4]). But there are also dissenting opinions, few, but they do exist, for example [9-21]. And scientific correctness does not result from democratic votes, but only from the quality of arguments.

In a very abbreviated manner (for more details see the cited literature), an important chain of arguments goes as follows: CO₂ is exchanged intensively between atmosphere and ocean respectively terrestrial biomass. The outflow from the atmosphere into these sinks occurs generally by diffusion, and diffusion principally scales with concentration. At least in the interesting area from 280 to 420 ppm, proportionality should be a good approximation. Furthermore, these outflow-processes are independent of whether and how much CO₂ is emitted into the atmosphere simultaneously (this inflow into the atmosphere is only important insofar as it, together with the outflow, determines how the concentration changes: the difference between outflow and inflow is the net flow, in whatever direction). Taking all of this into account, the outflow from the atmosphere should have increased from about 80 ppm/y at 280 ppm in the past (value given by IPCC, e.g. in [4]) to about 120 ppm/y at 420 ppm today, at least approximately. And since the concentration has risen, the inflow into the atmosphere must have risen even more, meaning, it must have risen a little bit more than approximately 40 ppm/y. The anthropogenic emissions of about 5 ppm/y are far too small, the lion’s share must come from natural sources. That seems to be logically mandatory. But what does the IPCC say about this? In numbers basically the same: Nature has contributed much more to the increase in atmospheric concentration than humans. According to Fig. 5.12 in [4], the emissions of CO₂ from natural sources have increased by 19.7 ppm/y (from 81.4 to 101.1 ppm/y;

calculated by 1 ppm equals 2,13 PgC), whereas the anthropogenic emissions only have reached 5.15 ppm/y. The numbers of IPCC are perfectly clear; it is only that IPCC states in its text that the increase in CO₂ concentration is man-made.

OK, if natural sources have increased, which ones? We do not know exactly. We only know that temperature has risen, increasing the outgassing from the ocean and the metabolic rate of biomass. However, how much that really increased the emissions is controversial. But if it is too small, other possibilities do exist: volcanoes, shifting ocean currents with different CO₂ concentrations, and some more. Availability is definitely not a bottleneck.

But speaking of the origin of the large amount of CO₂ in the atmosphere, another supplementary remark suggests itself: H₂O in gaseous form (water vapor) is another greenhouse gas, and it is even stronger and more abundant than CO₂. And just like CO₂, H₂O is subject to large natural exchanges, much larger than human releases. Regarding H₂O, we assume that the natural exchange processes are strong enough to determine the concentration, so that the anthropogenic releases have no great influence on it. Why don't we treat CO₂ the same way as H₂O?

So much for a brief overview of the open questions regarding origin and special treatment of CO₂, for more details see the cited literature. But of course, there are also rejections in literature. It's only that I have not found any that have convinced me, maybe I just have overlooked them. Anyway, a thorough and unbiased review of the considerations outlined here seems to be urgently needed. If it confirms the results described here, global warming is either caused by naturally released CO₂, or it is caused by completely different influencing factors and definitely not by CO₂. In both cases, a reduction of the anthropogenic emissions of CO₂ makes little sense. If such a review can be carried out easily, it should be possible to finish it with minimum effort and in a short time, and if it is not so easy, it is all the more necessary.

5. Summary and Conclusion

The existence and the size of the greenhouse effect have been heavily disputed for decades, with only small chances for an agreement soon, despite good arguments in favor of its existence. As a remedy, a novel model is suggested: A row of bodies, one after the other, one end of this row is constantly heated, the other end is constantly cooled down, and the bodies between adjust their temperature freely by IR-radiation from their neighbors. Then, another such body is inserted into that row, and the temperatures are observed. The body in front of the new one warms up (and that behind cools down). This clearly demonstrates the possibility of warming a warm body by a cooler one (if energy is still supplied from the outside, in the model by heating the first body, on the real Earth by the sun). The model also allows a rough confirmation of the usually given value of 33 °C for the size of the "natural greenhouse effect" by means of a completely new approach: This warming up of the Earth's surface corresponds to approximately half of the well-known vertical temperature spread in the atmosphere. As a consequence, this part of the discussion can hopefully be considered settled.

The question of how much the global temperature rises through continued anthropogenic emissions ("additional greenhouse effect") is more difficult to answer. Here, even the proposed model does not help, because the uncertainties are too large. Even more so, because there are also doubts about the true origin of the recent increase in CO₂-concentration and the different treatment of H₂O and CO₂ regarding human influences. Is the increase in CO₂ concentration manmade or is it predominantly natural? This is mentioned here as an open question with some reasoning as to why it seems to be natural, but a detailed discussion goes beyond the scope of this paper.

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