Chemie Ingenieur Technik

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Rethinking Climate Change on the Role of Human Power Generation, Alternative Perspectives, Potential Solutions, and a Plea for Action

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ABSTRACT

Climate change is typically attributed solely to greenhouse gases in the atmosphere. We propose a broader conceptualization of this complex challenge by considering the growing role of anthropogenic power generation and the Earth's delicate energy balance. In addition, we consider the impact of continued population growth and the growing need for energy. This integrated perspective may contribute to explaining the currently unexplained discrepancies in existing climate change models. In addition, we propose a forward looking strategy to move from pessimism to proactivity in mitigating climate change. For industrial production, there is a lever to change things by replacing existing processes with more efficient ones and by recovering low caloric heat. This can be paired with traditional carbon mitigation approaches. In this way, humanity is the cause of climate change, and humanity also has the tools to defeat climate change.

1 | What If? and Don't Panic!

Numerous scientific breakthroughs owe their origins not to a uniform methodology, but rather to a wide range of—at times hotly debated—approaches to scientific inquiry. Particularly in the middle of the 20th century, philosophy of science saw intense discussion around the question of how knowledge is best generated. The spectrum of perspectives ranged from strictly rationalist to deliberately unconventional and rule-challenging methods.

Karl Popper famously insisted that scientific theories must be falsifiable in principle to qualify as scientific at all [1]. In contrast, Kuhn emphasized the role of fundamental paradigm shifts, arguing that science progresses not linearly but through discontinuities marked by crises and scientific revolutions [2]. Feyerabend went further still, questioning the very notion of a universal scientific method with his provocative claim that "anything goes"—for him, the diversity of methods was not a weakness but the hallmark of productive science [3]. In addition, Lakatos, with his concept of "research programs" that distinguish between a stable "hard core" and a flexible "protective belt" of auxiliary hypotheses, offered a way of understanding scientific development as a structured yet adaptable process—neither strictly cumulative nor purely revolutionary [4].

Abbreviations: AAHR, additional anthropogenic heat release; AHE, anthropogenic heat emission; AHR, anthropogenic heat release; EEI, Earth's energy imbalance; ERF, effective radiative forcing; PA, phosphoric acid; PR, phosphate rock; REs, renewable energies; WCP, wet chemical process.

Yet not everything that can be known tells us what ought to be done. The frameworks developed by these thinkers illuminate how science constructs, challenges, and refines knowledge. But they do not provide normative guidance for how we should act in light of what we know.

This points to a deeper issue: Scientific insight requires ethical orientation if it is to become responsible action. As von Foerster emphasized in his second-order cybernetics, knowledge gains its full meaning only when situated within an ethical framework—one that encourages reflection on values, consequences, and the scope of human agency [5]. Responsibility arises in the context of uncertainty. Precisely in those domains where a research program has not yet yielded complete knowledge, decisions must nonetheless be made. His imperative to "act always so as to increase the number of choices" reminds us that methodology alone cannot determine the right course of action; it must be accompanied by a willingness to ask: Are we posing the right questions?

Given these epistemic and ethical reflections, it becomes clear why two popular works—Randall Munroe's *What If?* and Douglas Adams's *The Hitchhiker's Guide to the Galaxy*—can be seen as surprisingly fruitful sources of scientific inspiration [6, 7]. Despite their playful and provocative tone, both works share a fundamental premise: the importance of asking the right questions and the courage to think the unthinkable—without panicking.

Just as bold and unconventional thinking has historically led to groundbreaking discoveries, it is equally vital today to approach complex challenges such as climate change with the same intellectual courage—by questioning assumptions, broadening perspectives, and exploring alternative explanatory models.

2 | Why Do We Need a More Nuanced Discussion of Global Warming?

The planet we live on has, over millennia, reached a near equilibrium in terms of its energy balance. Despite the vast amounts of energy that come from the sun, enough is lost back into space that the planet's temperature was broadly stable until recently. Although some of this stability can be potentially attributed to anthropogenic CH_4 production in deep history offsetting natural cooling, the acceleration of human development has begun to initiate a change in the system [8]. In particular, the cumulative release of CO_2 from fossilized carbon into the atmosphere, where it traps some of the escaping radiation, has been sufficient to alter the energy balance such that a tiny fraction of the sun's energy is retained within the Earth's atmosphere, incrementally warming the planet. As greenhouse gases accumulate, the amount of energy trapped (represented by EEI, the Earth's energy imbalance) is increasing, at a rate of around 0.05 W m^{-2} $year^{-1}$ to around 0.9 W m^{-2} in the present [9, 10]. In terms of the total amount of energy reaching the upper atmosphere, this amount seems negligible, but it is the accumulation of this excess energy that drives the process of global warming.

Unlike several widely cited reviews that primarily frame climate change in terms of energy production, emissions reduction, or technological substitution, our approach takes a more nuanced systems perspective [11–15]. This perspective emphasizes energy conversion processes, thermodynamic constraints, and the interaction between technical, societal, and organizational factors. Instead of focusing on individual technological solutions, we emphasize the role of science and engineering in developing comprehensive, system-level strategies for climate mitigation.

The scientific and political communities are in agreement that urgent action to reduce the amount of greenhouse gases in the atmosphere by both a reduction in emissions and the capture and removal of CO_2 is required to keep the planet within reasonable temperature bounds. Implementing these behavioral and technological changes across the globe is a slow process, and we are edging closer to the boundaries we have set. At this stage, we must use every available tool to slow the rate of warming while shifting to a new energy approach.

Did we ask the right question?

What if greenhouse gases are not the only reason for anthropogenic climate change?

What if it were possible to rethink climate change in a way that would help to develop further solutions for mitigating the challenges of climate change?

Whether or not one agrees with the ideas presented here, the reader is respectfully encouraged to approach them with an open mind—and to reserve judgment until after careful reading.

2.1 | Thinking the Unthinkable: A Plea for Thinking Beyond Carbon Dioxide

The debate surrounding climate change has been unnecessarily contentious, and this has had a polarizing effect. As greenhouse gas output has tracked industrialization, population growth, and other trends in development, it is straightforward to correlate any of these with the warming effect. This does not imply causality. Unfortunately, one casualty of this relationship is the nuanced discussion of the energy output of humans. All energy ends up as heat; so many forms of anthropogenic energy use add heat to the atmosphere. This has led to some people suggesting that it is this direct warming (rather than the effect of the greenhouse gases which are a by-product of the power generation[1]) that is the cause of global temperature rise. This argument fails on two levels; first, it ignores the established physical principle of the absorption of longwave radiation by greenhouse gases, and second, the amount of energy that humans produce is nowhere near enough to generate the observed warming. This does not mean, however, that the contribution of heat of anthropogenic origin should be discounted.

The world's population currently consumes over 620 EJ (172 222 TWh) of energy per year. Not all of this energy can be considered anthropogenic in origin, so we can exclude most renewable energy sources from this total, because wind and hydrological energy are already in the system and will eventually become heat in the absence of human intervention. The currently negligible amount of geothermal energy is a borderline case.

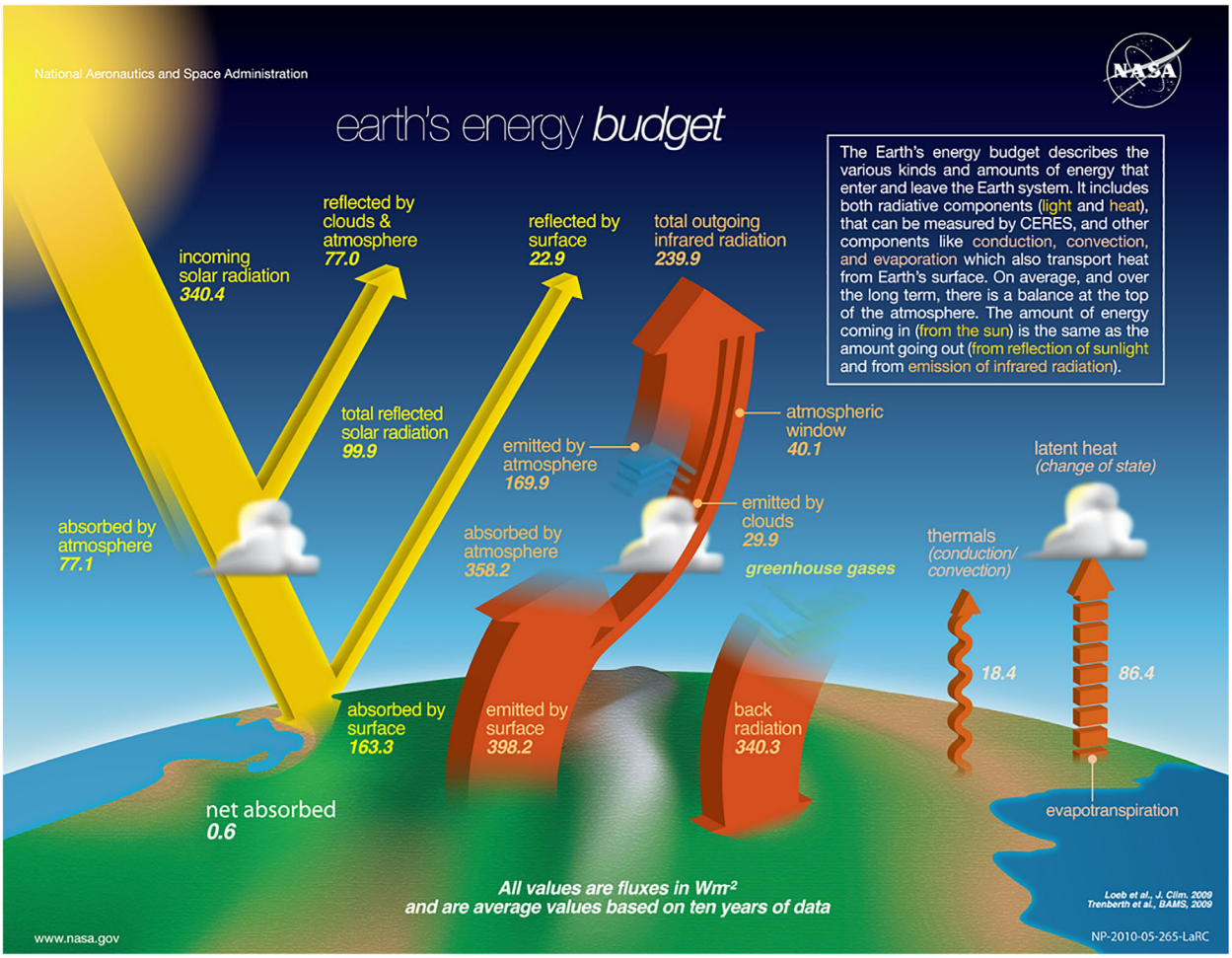

FIGURE 1 | Energy balance of the Earth. In the present situation, there is a net energy input of 0.6 W m^{-2} of solar energy. This illustration already reflects the influence of greenhouse gases. Graphics by NASA Earth Observatory/NASA Science Mission Directorate. Public domain [18].

The energy is in the Earth's system, but its release into the atmosphere is accelerated by the use of geothermal energy. Removing these sources leaves us with a consumption of fossil fuels and nuclear energy of 514 EJ (142 778 TWh), which averages out as 0.032 W m^{-2} across the Earth's surface. We refer to this nonrenewable heat flux as AAHR (additional anthropogenic heat release) to distinguish it from AHR (the total anthropogenic heat release).

The polarization of the debate on global warming has led to this number being dismissed as negligible. The narrative, designed to quash climate skepticism rather than to critically assess the contribution, runs as follows:

- This is a distraction from the urgent need to manage greenhouse gases.
- This amount is negligible compared to the amount of energy from the sun.
- If we compare the annual rate of anthropogenic heat of 0.032 W m^{-2} with the effective radiative forcing (ERF) from CO_2 (i.e., the cumulative warming effect of CO_2 since 1750) of 2.28 W m^{-2}, or the total anthropogenic atmospheric forcing of 2.79 W m^{-2}, the AAHR is only 1.4% or 1.14%, respectively [16, 17].

Figure 1 illustrates the Earth's energy balance. As can be seen, most of the solar energy is ultimately reflected or emitted into space. Only a minor fraction of 0.6 W m^{-2} remains on the surface.

The situation changes if one considers human power generation. As all energy finally results in thermal energy, an additional heat input occurs in the lower levels of the atmosphere. This section of the planet's gas envelope possesses the highest density and, as such, also has the highest heat capacity of all atmospheric layers. In other words, the small part of the atmosphere marked orange in Figure 2 behaves like a black radiator. Subject to wind drift, it is in constant motion around the Earth. As human activity produces heat on the night side of the Earth as well, thermal energy is released day and night to the part of the atmosphere nearest the Earth's surface. Consequently, heat is emitted from this "heat shell" into space and onto the Earth's surface, regardless of whether it is a landmass or an ocean and regardless of whether it is tropical or arctic. This model provides a simple explanation for the effective transport of heat into the oceans and polar regions.

Let us take an objective perspective on these arguments:

First, should we be concerned about being distracted? Humans are capable of doing more than one thing at a time, and a recent shift to include consideration of methane emissions in addition to

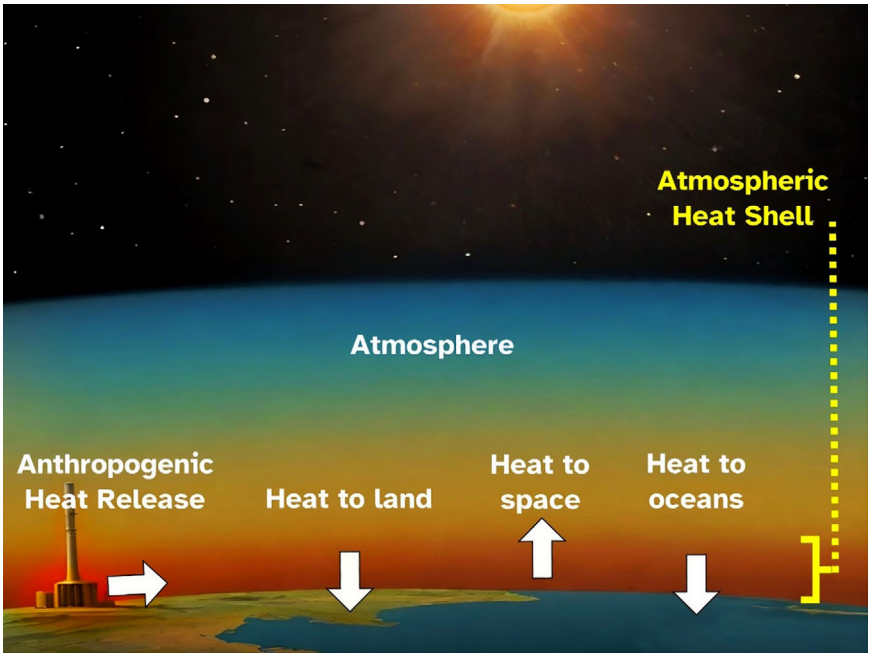

FIGURE 2 | The influence of human thermal energy release on the densest part of the lower atmosphere. Human activity generates a "heat shell" that distributes over the entire planet's surface, warming both landmasses and oceans, as well as the tropics and polar regions.

CO_2 has shown that humankind is quite capable of multitasking. Furthermore, as we discuss below, reduction in CO_2 emissions is the simplest way to reduce AAHR.

Second, is solar radiation relevant? We have seen that the world's solar budget is close to equilibrium in the absence of greenhouse gas forcing, so the total amounts of energy moving in and out of the system are largely irrelevant.

Third, why would rigorous science choose to include radiative forcings of 0.05 W m^{-2} from contrails and from stratospheric water vapor in the calculation of anthropogenic ERF but exclude AAHR at 0.032 W m^{-2}? [12].

Finally, should we compare the current annual contribution of anthropogenic energy with the ERF at all? ERF is the cumulative impact of CO_2 since 1750. Why would we compare an instantaneous rate with a cumulative total expressed as a rate, rather than compare like with like? Comparing the EEI at 0.96 W m^{-2} with the instantaneous rate from additional anthropogenic heat (0.032 W m^{-2}) gives a proportion of 3.3% [12]. Alternatively, we could approximate the cumulative impact of AAHR since 1750 by making a conservative assumption that the proportion of this energy retained in the atmosphere is 70% per annum (less than the 85% of outgoing IR radiation retained [16], such that most of this heat is lost from the system within a few years. Here, the approximated forcing of 0.1 W m^{-2} based on recent historical records is perhaps more directly comparable with ERF and represents 3.7% of the total anthropogenic ERF of 2.79 W m^{-2} [13–15].

In summary, the effect of additional anthropogenic heat in 2023 is warming the planet at a rate of over 3% that of the rate of atmospheric warming, and if recent trends in anthropogenic heat output continue, this is likely to approach 4% of current EEI by 2050 [19–21]. It is important to stress again that the effects of heat can be expected to have a low residence time, and unlike greenhouse gases, do not have persistent impact. A further critical consideration is that fossil fuels contribute to 98% of the AAHR, representing an additional incentive to reduce reliance on these. We must also consider the further feedback with greenhouse gases; the more heat trapped, the less we wish to produce in the lower atmosphere.

Taking a global and longer term perspective is useful, but anthropogenic heat can also be expected to have a transient warming effect near the Earth's surface close to the source. The work of Chen et al. shows that AHR (as distinct from AAHR) elevates global mean temperatures by 0.02°C and 0.05°C for land and sea surfaces, respectively, but perhaps most importantly, this effect is highly spatially variable, being concentrated near the source before it is more widely dissipated [22, 23]. This leads to maximum summer temperatures up to a degree warmer and longer duration of heat waves, with an expectation of increased heat-related mortality. If superimposed on a gradual warming, this effect will be exacerbated.

Although reducing AAHR to zero is likely to be challenging, given the potential short-term impact, we can choose to reduce this if we consider it to be worthwhile. If we consider that current trends in observed global CO_2 emissions continue to increase every year, broadly in line with additional anthropogenic energy consumption at a geometric rate of around 1.4% per year, a halving of AAHR would effectively buy the world an extra year for action. Similarly, the accumulated energy from 30 years of AAHR above the 1996 level (Table 1) is broadly equivalent to 1 year of warming, and this amount continues to increase every year, and a greater proportion is trapped as greenhouse gases increase. Our attempts to manage CO_2 are falling short, and we are heading dangerously close to global tipping points, which may have catas-

TABLE 1 | Human energy surplus above the 1996 level in the period from 1997 to 2022.

Time period	1997–2022
Accumulated energy surplus on the basis of 1996[a]	2926 EJ812 685 TWh
Effective solar energy input per year[b]	3408 EJ946 786 TWh
Percentage of annual solar energy input	91.8%
Equivalent days[c]	332.9 days

[a]Excluding renewable energies.
[b]Of incoming ~340 W m^{-2} 0.6 W m^{-2} becomes effective on the Earth's surface.
[c]Basis = 365 days per year.

trophic consequences. Figure 3 illustrates the amount of AHR to the atmosphere. Can we afford to dismiss this contribution to warming? The scale of the problem is very large, and every little bit helps. This is a lever that we can use to reduce the rate of warming, so why ignore it? Can consideration of human heat production help buy us a critical fraction of a degree that might help us stay within our planetary boundaries? Can we capture heat at source and use this energy to help with carbon capture?

Table 1 shows the human energy surplus on the basis of 1996 in the period from 1997 to 2022. The accumulated heat exceeding the amount of 1996 is 3108 EJ (863 567 TWh), which is 91% of the amount of net solar energy input on the Earth on the basis of 0.6 W m^{-2} (For more detailed information, please refer to Table S1) [13]. This amount corresponds to 332.9 days, which is almost a whole year of solar energy input as it becomes effective on the Earth's surface.

Not to be misunderstood: What we are saying here is that human heat production is affecting the lower atmosphere much more than the greenhouse gas story alone can explain. Again, we are not questioning the scientific work of climate research, but we are pleading for openness to an alternative working hypothesis to explain the observations. As a result, truly speaking, we must conclude that mankind has been far too hesitant to act on this basis, and the pressure to act is greater than anticipated.

What we are seeing is unprecedented population growth, which is well correlated with energy demand, power generation, and a well-correlated evolution of the Earth's surface temperature. The working hypothesis presented here is helpful insofar as it sheds light on human power generation, occurring day and night. In today's highly technologized world, heat released by human activities significantly disturbs Earth's radiative balance. Unlike solar heating, which mainly occurs during the day, human-generated heat is added to the lower atmosphere continuously, including at night. This reduces the planet's ability to release excess heat from the dark side of Earth. As a result, the combined effect of incoming solar radiation and technical heat emissions raises the overall temperature of the lower atmosphere. This warmer atmosphere then radiates energy both upward into space and downward toward the Earth's surface, contributing to the observed warming of oceans and land. When the additional heat-trapping effect of CO_2 and other greenhouse gases is taken into account, the mechanism behind the rising global temperatures becomes clear.

To give an idea of the magnitude of mankind's impact on our planet, examples of industrial activity are given. This also serves to illustrate that human power generation—which ultimately equals human heat production—fits well into this picture. This scale of human activity seems incredible because we are talking about effects of human action on a planetary level. In fact, AAHF fits well with other processes, such as the production of ammonia, methanol, or the human mobilization of soil and rock.

If we look at nitrogen fixation, chemical nitrogen fixation has been reported to produce between 150 and 184 million tons of ammonia in 2024 [24, 25]. This makes NH_3 ammonia production one of the most important emitters of CO_2 and heat, with 1%–2% of global power generation, 5% of natural gas and 1.6% of global CO_2 emissions, 1.4% of global fossil energy consumption [26]. On the contrary, biological nitrogen fixation is reported to range between 120 and 200 million tons per year [27]. In other words,

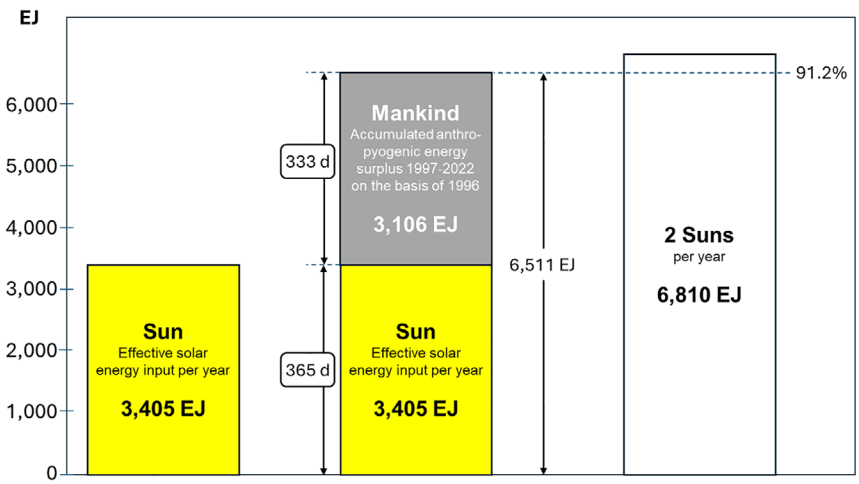

FIGURE 3 | Graphical illustration of AHR to the atmosphere. From 1997 to 2022, a total of 3106 EJ (863 567 TWh) was released into the lower atmosphere. We consider this amount of energy to be contributing to climate change by producing a so called heat shell around the globe that acts as a black radiator.

annual human nitrogen fixation has already reached at least 80% of natural levels. Another example is methanol production. In 2022, this was 112 million tons compared to 93 million tons of fuel ethanol, which is the most abundant alcohol obtained from fermentation [28, 29]. Another one is erosion, where human mobilization of soil and rocks (75 Gt a^{-1}) exceeds the natural value of 21 Gt a^{-1} by a factor of 3.6 [30]. The technical heat input to the Earth's surface was 514 EJ (142 778 TWh) in 2023, compared to 15 442 EJ (4 289 444 TWh) of remaining solar heat [12]. The significance of these numbers becomes more comprehensible when one considers the extent to which human activities are approaching or even exceeding those of nature. In other words, anthropogenic heat production must be considered in the scale of technical activities such as ammonia production and others. Last but not least, 1% of the world's land mass is used for urban and built-up areas. This includes settlements and infrastructure [31].

It is therefore not surprising that the world's human population has an impact on global temperature. If one compares the Earth's temperature anomaly over the last 150 years with annual carbon dioxide emissions, primary energy consumption, and measured atmospheric CO_2 levels, there is a parallel increase in all of them [11, 32–34]. What we propose is that the causes of climate change could be seen not only in the higher levels of CO_2 in the atmosphere but also in human power generation or consumption, which, in 2022, was 81.5% from fossil resources, that is, carbon-based [11].

As a solution, we propose making technical use of the heat potential in both air and water. Of course, mankind will probably not suddenly have the necessary tools at hand, so we leave this question to human ingenuity. On the other hand, the situation may be better than feared, because we are already using low-temperature heat, for example, by using thermoelectric devices, membrane distillation, and others. To be true, heating rivers by any power plant and complaining about energy losses is nothing that mankind should be proud of in the year 2025.

What if the clue to solving the problem of global warming is reducing human power generation rather than emissions? ***What if*** the operation of nuclear power plants is part of the problem as well as part of the solution? Of course, there are no CO_2 emissions, but there are significant heat emissions (which we want to be understood in a technical, not an ideological, sense).

3 | What Are the Consequences?

We are witnessing a growing striving of more and more people all over the world for a Western standard of living in a shorter and shorter period of time, something which is in fact a steady increase in technologization. Already today, computers, the internet, and so forth are indispensable parts of life in every country of the world. This increasing degree of technologization in the lives of an increasing number of people in every part of the world is spiraling energy consumption upward. If we are serious about addressing climate change, humankind needs to rethink these effects.

Energy is a precious commodity, and access to affordable and sufficient energy is vital not only for industry. For ethical reasons alone, people need to be provided with energy on reasonable terms. Access to energy is a human right, just like access to clean water, food, and other goods. Rethinking the world means scrutinizing everything.

For this reason, it is worth considering every major emitter as an energy source. Data centers, for example, consumed about 0.738 EJ (205 TWh) worldwide in 2018, which was 1% of that year's global electricity consumption [35]. In 2024, the figure was 1.49 EJ (415 TWh), accounting for 1.4% of global electricity consumption that year. Estimates project a rise to 3.40 EJ (945 TWh) by 2030 [36]. Instead of cooling, it is recycling, using, and valorizing this waste heat, which is the option, that allows us to combat the release of heat into the near-surface atmosphere. Recycling, using, and valorizing this waste heat rather than using more energy as cooling allows us to combat the release of heat into the near-surface atmosphere.

We need a strategy that goes beyond the use of renewables, which are generally seen as the savior to solve the world's energy problems. A full energy transition will take time. The hope that renewable energy (RE) will someday help us solve all our problems is too much of a comfort blanket, stifling the development of inventive near-term solutions.

4 | Call for Action

Worldwide, the industry is caught in a trap. There is a need to produce products and consumable goods in an energy- and resource-efficient manner, and the level of technology achieved to date is impressive. Yet, the vast majority of processes applied in industry today date back to the last century. The greenhouse gas theorem was the pillow that lulled us into a false sense of security that simply switching to non-CO_2 emitting energy sources would be enough. But this is not the case. The German Energiewende is an example of how difficult it is for even wealthy countries to pave the way for CO_2 and heat emission neutrality. In addition, contrary to what is currently being discussed, it is not just local heat islands that exacerbate global surface warming. The unwelcome news is that renewables alone will not be enough to meet human energy needs in the short term, simply because there is not enough installed capacity. In addition, where all the raw materials for photovoltaics, solar thermal, and wind turbines will come from remains a question. Part of the truth is that human population—which is expected to keep on growing at least until 2050—will continue to increase demand for energy and goods. The good news is that there are processes that can address this urgent situation. The other good news is that in principle there is a way to turn back the climate wheel to a certain extent. At least we can delay the effects. Concisely, switching energy supply to renewables is one pillar, new energy-efficient processes another. One door opener is replacement. Another is recycling of heat.

4.1 | Replacement as Innovation Strategy

The industry needs to act. Not only has it become clear that fossil raw materials can be used as a means of forcing geopolitical developments, but it has also become clear that industrial companies can be extorted if they too willingly rely on oil and gas.

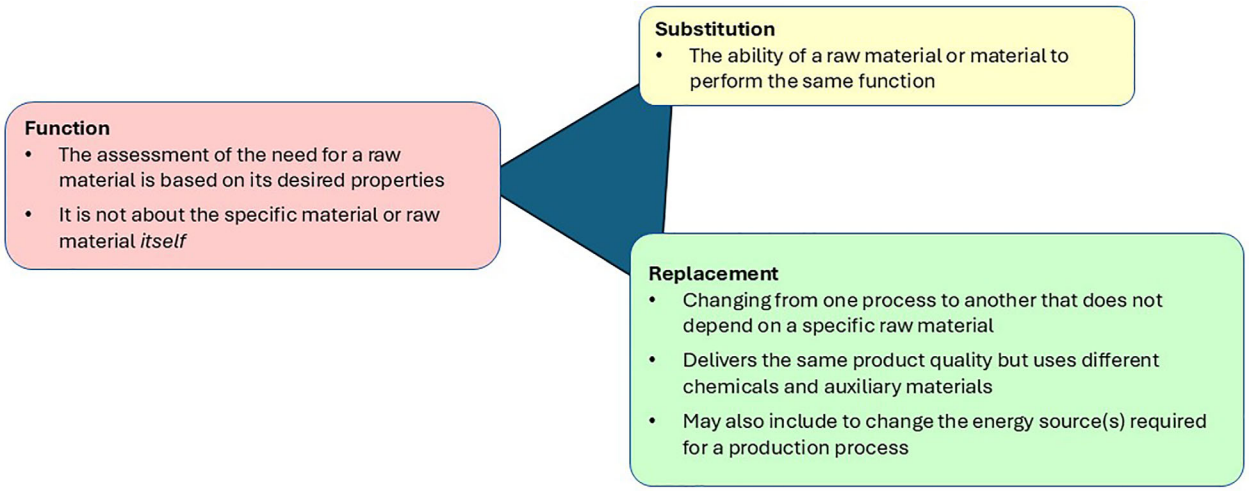

FIGURE 4 | Replacement is the substitution of one process for another that is not dependent on a particular raw material while producing the product(s) with no difference in quality but using different chemicals and auxiliaries [28].

However, the reason for using fossil fuels is much more of a must than a will. At present, there is simply no alternative to most of the processes that depend on these very feedstocks.

On the other hand, this situation also provides a clue to solving the problem: replacement. This term stands for the exchange of one process for another that is not dependent on a particular raw material whose availability or price is critical. The replacing process provides the identical product(s) with no difference in quality but uses different chemicals and auxiliaries. Replacement also encompasses the exchange of the energy source(s) required for a production process [37].

One approach is to replace energy- and raw material-intensive processes, which, in the worst case, also produce substantial amounts of waste that require technical treatment. As shown in Figure 4, replacement refers to the exchange of one process for another that is not dependent on a particular raw material whose availability or price is critical. The replacing process provides the product(s) with no difference in quality but uses different chemicals and auxiliaries. Replacement also includes changing the energy source(s) required for a production process. It should not be confused with substitution, which is the ability of a raw material or substance to perform the same function as the raw material or substance being substituted [28].

The production of phosphoric acid (PA) from phosphate rock (PR) is an instructive example of how this can work. Currently, PA is produced through the wet chemical process (WCP) by digesting PR with sulfuric acid. Given the above, the WCP is outdated because of

- The need for sulfuric acid. The acid is produced from sulfur, >75% of which comes from oil and gas processing. As the supply of fossil fuels diminishes, as has been seen in response to the geopolitical developments in 2022, there is an impact on the supply of sulfur and also on the supply of sulfuric acid, which, in the long term, limits the supply of P fertilizers for a growing world population.
- Energy consumption. The production of PA requires a conventional energy supply, that is, fossil energy resources.

As an example, to *replace* the established WCP, a completely different technology is needed that avoids the use of fossil energy raw materials. To achieve this, the PARFORCE process (Phosphoric Acid Recovery from Organic Residues and Chemicals by Electrochemistry) was developed as a more energy- and resource-efficient alternative [38]. The process is run with hydrochloric acid (HCl) or nitric acid (HNO_3). This way, the energy-intensive production and purification of the coproduct gypsum dihydrate is circumvented, and the process consumes 150–300 kWh per ton of PA (54% P_2O_5) compared to 2000–3000 kWh per ton of 75% PA (54% P_2O_5) of the WCP. It is important to note that these ranges vary depending on the type and quality of the feedstock. In other words, under optimal conditions, PA production can be realized at ~10% of the energy expense of now. In contrast to other PA production processes, the PARFORCE technology uses electrical energy only, and the generation of waste is kept to a minimum. It can be operated in an environmentally and climate-friendly manner using RE sources, such as the abundant solar energy available in Africa [28]. This is a textbook example of how replacement can enable industry to move to climate-neutral processes that make a real business case.

4.2 | Recycling of Heat

Another strategy is to optimize the use of low-temperature heat. It is imperative to accumulate, recover, and reuse heat, regardless of whether it is process heat or waste heat. For too long, it has been easy and convenient to dispose of the thermal energy left over from power generation in rivers. As a consequence, there is no ability to utilize low-temperature heat below $T = 120°C$ on a technical scale. Even in 2026, we see power generation efficiencies of about 33%–46% for coal, gas (OCGT), and nuclear, with only the most recent gas combined-cycle (CCGT) plants reaching 52%–60% [39]. This is not really an example of investing the best of human ingenuity to make it better.

Thus, there is a need to recover heat from low-temperature heat sources, concentrate it, and produce process energy. We're not saying these technologies are already in existence. It's possible they are, but they are not currently operational. We wish to emphasize that this is not a call to disobey the laws of thermodynamics. What we wish for is an open-mindedness toward approaches that split a given temperature level into concentrated heat and cooler leftovers. This will, of course, require energy because it is impossible to split an energy level into two different levels without expending energy. However, this process must be far more efficient than current heat pump technology. We need new ideas that go beyond what has been known for 200 years. Although it is not feasible to prevent all the energy that is generated ending up as heat (in air, land, and sea) due to the second law of thermodynamics, effective repurposing of excess heat energy can effectively reduce the requirement for power generation.

There are different scenarios for how to do this. One could be to extract heat energy from seawater. For example, the temperature of the Adriatic Sea has increased by 1.5–2.0 K in the last 25 years. This is not much in absolute terms, but the results are impressive. Be it the increased number of Mediterranean tropical-like cyclones (medicanes) in the Mediterranean or the Vb-track cyclones, also called Genoa Lows, which unfold a strong destructive force when they reach Central Europe. Humankind has not yet understood how to use this thermal battery, not because it does not work, but because it has never really tried.

There are four issues that address how the planet and the industry can both benefit:

- Increasing the exergy fraction of energy to optimize the energy input at the expense of waste heat.
- Utilizing waste heat or low-temperature heat.
- Replacement of existing processes through more efficient ones.
- Long-term heat storage.

Many textbooks provide explanations as to why an approach may be ineffective. On the contrary, if science were to take every concern into account regarding the viability of a given idea, human progress may have ceased at the same time as apes descended from trees—if they had even done so at all.

4.3 | A Deep Thought: Pose the Right Questions!

The key question is not who should act first, but rather where to begin. The answer lies in one of humanity's most defining traits: ingenuity.

To summarize the above argument:

1. All forms of anthropogenic power generation, regardless of their source, ultimately contribute to the accumulation of heat in the Earth system.
2. As of today, there is no technical oversupply of RE readily available that can simply be harvested without substantial infrastructure and innovation.
3. Given the current global population and its likelihood of growth, there is an undeniable need for large-scale energy generation. A growing population means growing energy demand. However, we cannot meet this demand with CO_2- and heat-intensive power generation if we are to take climate protection seriously.
4. Although reducing CO_2 emissions is essential, we must assess the effectiveness, costs, and ethical implications of such measures in a realistic and integrated manner.

There is little to suggest that these fundamentals will change in the near future. However, resignation is not a strategy. Rather than succumbing to pessimism, we should seek to rediscover the joy and purpose of shaping our future. Humanity possesses an extraordinary capacity for innovation and problem-solving—tools that are more vital now than ever.

Given the dynamics of population growth and technological expansion, it is highly probable that anthropogenic power generation will continue to increase. This is the premise we must acknowledge—our starting point: a world of 8.1 billion people and a global annual power generation of 604 EJ (167 789 TWh) [40]. Both figures are growing. One might be tempted to idealize a return to the population levels of 150 years ago, that we must return to a preindustrial state. Yet, such considerations are not only unrealistic but also fraught with ethical concerns. Who would decide? Who would be affected first? The goal must therefore not be to restore a lost past but to create a future in which the planet regains its thermal balance.

It will not be the same Earth as before climate change—but it can be a stable and sustainable one. Apocalyptic narratives or dystopian visions of collapse are of limited value. Rather than inspiring change, they often serve to paralyze action. What is needed now is a sober recognition of our situation—and a willingness to address it constructively. If we are indeed facing an overproduction of anthropogenic heat, then the response must be guided by technical creativity: Finding ways to utilize or redistribute this heat for the benefit of all. Some may argue for an immediate ban on non-RE sources. However, the current technical availability of RE is insufficient to meet global demand. A sudden cessation would result in severe energy shortages with profound societal consequences. Whichever path is chosen, there will be a price to pay. The question is: Who will pay?

Ultimately, the way forward depends on human ingenuity and the technologization of everyday life. This is where engineering and science emerge not as abstract disciplines but as vital providers of solutions—tools for restoring balance, enabling adaptation, and reshaping the relationship between civilization and climate.

4.4 | Theoretical Postscript: A Living Research Program

Lakatos developed a nuanced model of scientific progress known as the "research program." According to his approach, science advances not through isolated hypotheses or abrupt revolutions but through structured systems of thought built around a stable "hard core" of fundamental assumptions, safeguarded by a

flexible "protective belt" of auxiliary hypotheses and heuristics. Scientific progress, Lakatos argued, occurs when this protective belt is revised and expanded in response to new empirical observations—a process he called "progressive problem shift." Conversely, programs that fail to adapt become degenerative, clinging to outdated models and losing empirical relevance [4].

Within this framework, the dominant paradigm of climate science—centered on the role of greenhouse gases, especially CO_2, as the primary driver of global warming—can be seen as a research program. Its "hard core" consists of the assumption that greenhouse gases are the primary cause of warming, whereas its "protective belt" includes auxiliary hypotheses such as carbon pricing, emissions targets, mitigation scenarios, and technological offsets.

The proposal presented here does not seek to refute the hard core; rather, it calls for an expansion of the protective belt by incorporating direct anthropogenic heat emissions (AHE) as an additional explanatory factor. This addition is not an anomaly to be dismissed but a conceptual enrichment—a progressive modification that enhances the program's comprehensiveness, empirical adequacy, and responsiveness to emerging conditions. In Lakatosian terms, scientific progress occurs not only through abrupt paradigm shifts but also through the methodical evolution of research programs that absorb new questions and shift perspectives. Thus, acknowledging the relevance of AHEs is not a contradiction of existing climate science but an expansion of its explanatory power—a sign of a living science that learns, evolves, and adapts in the face of new challenges.

5 | What If?

What if these thoughts were true? Then humanity would need to fundamentally rethink the way it generates heat. We would have to harvest our energy directly from the sun—not just in a literal sense but also in a structural sense: easily, efficiently, directly, and in harmony with the planet's thermal balance. Some may argue that this is unrealistic. That lost heat cannot be recovered from the atmosphere or the oceans. That the necessary technology does not yet exist. But that is not proof of impossibility—only a reflection of our current imagination, not of our actual limits.

The fact that something has not yet been invented does not mean that it cannot be done. It simply means that, until now, no one has yet had sufficient reason—or urgency—to try.

But today we are a step further. So, let us get started.

6 | Conclusion

This article offers an alternative lens through which to view climate change: ***What if*** the problem is not just one of emissions, but additionally one of heat generation? Although interpretations may vary, highlighting the thermal impact of human-generated energy can provide new insights—and inspire new forms of action.

Currently, global power generation contributes approximately $0.0324\ W\ m^{-2}$ of direct heat to the earth system—an amount equal to 3.3% of the net solar energy input to the surface ($0.96\ W\ m^{-2}$). This anthropogenic heat enters the lower atmosphere continuously, even at night—precisely when the Earth would otherwise release heat into space to maintain radiative balance. Rather than replacing greenhouse gas effects, this heat adds to them—further complicating the challenge. One way forward is replacement: exchange existing systems for more energy-efficient technologies. Another is to apply the "heat theorem": manage energy as a finite thermodynamic resource and recycle it in closed loops—much as we strive to do with materials in a circular economy. Action is needed. It will take time. But it is worth the effort. The conceptual tools are already within reach.

It is now up to us to explore new ways of thinking and reasoning and to imagine different solutions to a problem we thought we already understood. We have solutions at hand; let us get started!

7 | Final Remarks and Outlook

Perhaps our current situation is like a hot air balloon in flight—slowly ascending, not because we want to go higher, but because more and more heat is building up underneath us. We have enlarged the balloon, improved it, stabilized it—but we have rarely asked ourselves whether we really need all this heat to stay in the air. Now is the time to not only course correct but also to rethink the whole principle: how we ride and on what. Maybe we need to learn to force altitude not with more and more flames, but through clever, skillful navigation, through balance. Not through more heat—but through a better understanding of buoyancy and (thermodynamic) limits. For even if we cannot return to the solid ground of old, we can find a point where we do not have to climb any further but can stand stable and steady in the air—between heaven and earth, carried by what we can control, not by what we unleash.

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Data Availability Statement

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

Endnote

[1] We use the term "power generation" instead of "energy production" or "energy consumption" because, according to the laws of thermodynamics, energy cannot be produced or consumed; it can only be converted into another form of energy. All energy sources used by mankind will ultimately become thermal energy, also known as heat.

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Supporting Information

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