



Resolving Global Warming Issues from the Earth's Energy Balance

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Abstract. Many scientists and researchers have expressed concerns about changes in the Earth's climate. Recent years have seen various disasters arising from climate change, and the government has spent billions of dollars to resolve or adapt to this issue. However, climate-related disasters have shown no trend to end but instead intensified during the past decades. To improve the current environmental issues, humans must focus on the root cause --- the "unbalanced" energy flow in a warming climate. This study summarizes and evaluates many practical strategies for tackling global warming issues, including renewable energy exploitation, engineering, and anthropocentric approaches. This paper discusses the basics of global warming from the Earth's energy balance perspective, elaborating on its causes and proposing various potential methods that may be applied in the future.

Keywords: Global Warming; Energy Balance; Solutions.

1 Introduction

The environmental issue, particularly global warming, has become one of the most severe problems that threaten all living creatures on Earth. Global warming has been intensifying ever since the Industrial Revolution around 175⁰ [1]. Despite natural causes or the so-called internal climate variability, anthropogenic forcing has contributed 0.8 to 1.2 degrees of global temperature increase from 1850-1900 to 2010-2019 (Fig. 1), and the most significant factor in human-caused global warming is the unprecedented high concentration of greenhouse gas in the atmosphere, mainly resulting from burning fossil fuels such as oil, gas, and coal, as demonstrated by the newly released IPCC report [2]. Therefore, modulating greenhouse gas (e.g., carbon dioxide, methane, and dinitrogen oxide) concentration in the atmosphere is essential to resolve global warming issues.

The continuous warming temperature has led to multiple devastating effects: extreme droughts, floods, wildfires, hurricanes, and other disasters. As greenhouse gases block the outward-flowing solar energy, incidences of iceberg melting, sea-level rise, hydrologic oxygen loss, and associated environmental problems (e.g., heat waves, cold extremes, and floods) have become more frequent. These impacts associated with the

warming Earth are felt by all humans in one way or another, thus contributing to socio-economic issues of poverty, displacement, hunger, and social unrest.

Although global warming has caused a wide range of disasters, there are multiple ways to mitigate or adapt to global warmings --- such as turning to biofuel and thermal energy, reducing the total input of solar energy, and developing more efficient technology, educating citizens and enforcing environmental-friendly laws---but many have proven either unrealistic or ineffective. Therefore, we need more research on the pros and cons of current methods or solutions to global warming. Specifically, this study summarizes and evaluates available global warming solutions from a new angle: the Earth's energy balance. The effectiveness of multiple solutions and their feasibility to resolve global warming issues will be discussed comprehensively throughout the manuscript.

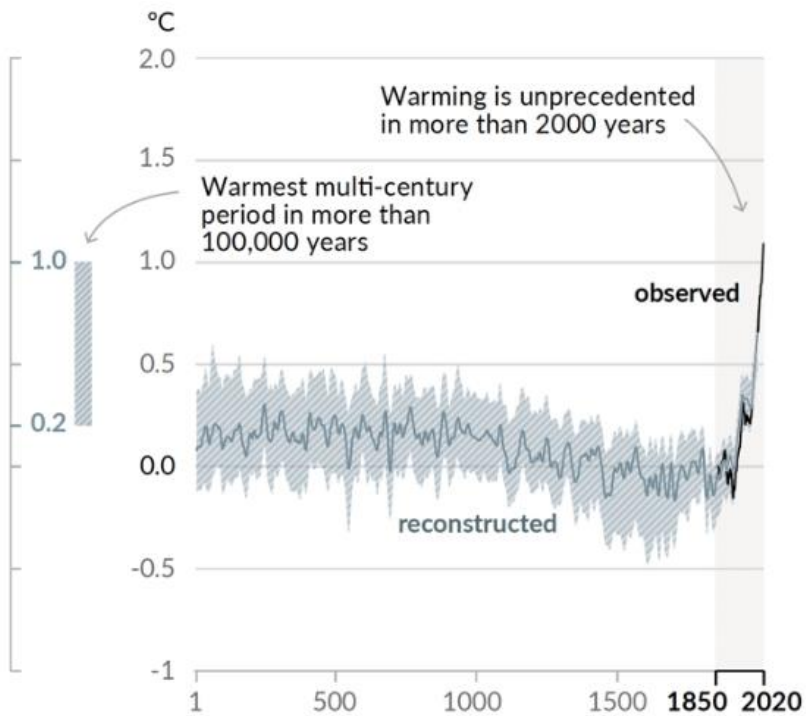


Fig. 1. Change in global surface temperature (decadal average) as reconstructed (1-2000) and observed (1850-2020) (IPCC, 2021)

2 Global Energy Balance

It is widely accepted that the Earth is a closed system, the energy balance of which relies on steady absorption from the sun and the constant output to space. In energy exchange, the atmosphere is essential to keep the heat on Earth so that creatures can thrive. If Earth did not have an atmosphere, the surface temperature would be minus 18

degrees, a condition impossible for most animals or plants to survive. However, in recent decades, the issue seems to be "high" global temperature, resulting from artificial disruption of the natural energy cycle.

To resolve the problem of increasing temperature, scientists must first understand the direction and magnitude of energy flow on the planet. The system's input pattern is as follows: The sun's radiated solar energy is directly absorbed by the atmosphere or the surface, while a portion of the total input is reflected (about 30%). When the energy is fully absorbed, the next part --- energy emission would occur. The energy absorbed by the atmosphere flow in two directions to the ground or back to space, and the heat energy of the ground would also flow to the atmosphere in three ways: thermal energy, vaporization, and direct flow. In every circle, the total amount of emission from the atmosphere would equal the total input from the sun, or else Earth would be too hot or cold to live.

Figure 2 shows the global energy transfer and budget estimated based on observational data^[3]. The Earth's energy balance (e.g., greenhouse gas effect) provides a fundamental and alternative way to understand global warming and its solutions. When humans started to release greenhouse gases (i.e., use of fossil fuels from the first Industrial Revolution), especially carbon dioxide, into the atmosphere, the atmosphere's ability to keep the heat on Earth (or the so-called greenhouse gas effect) has been boosted and accelerated. Specifically, heat would be brutal to flow from low altitudes to space since the trace gases' properties make them conservative of heat. Therefore, the two fundamental solutions are either to reduce solar radiation from the sun or greenhouse gas concentration in the atmosphere since there are three primary stages in global heat circulation: "absorption", "emission", and "reflection".

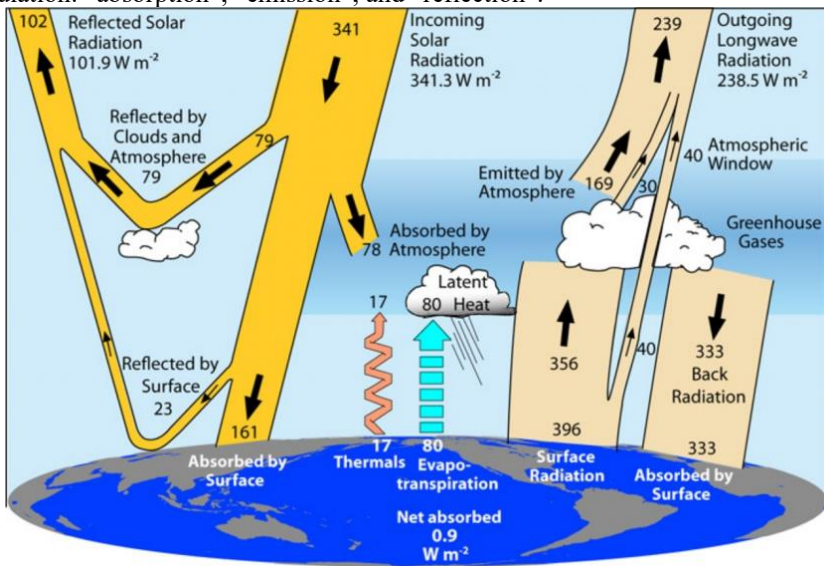


Fig. 2. The Earth's Energy Flow and Budget^[3]. The unit is W/m².

3 Global Warming Solutions

Previous studies have reported and discussed global warming causes, effects, and applicable solutions [4-6]. This study summarizes current methods (i.e., renewable energy, mirror construction, and anthropocentric approaches) and proposes energy balance-related solutions to global warming.

3.1 Mirror Construction: An Engineering Approach

This study first proposes an engineering approach focusing on the stage of "reflection" in the Earth's energy transfer. This method, referred to as mirror construction, considers the albedo effect of the Earth's surface by setting up large-sized mirrors (either on the surface or near the top of the atmosphere) to reflect incoming shortwave solar radiation. Though this specific global warming solution seems ideal, it would be a potentially applicable method to tackle global warming in terms of the global energy balance once the technological barriers are resolved.

Some may argue that it is impossible for the mirror construction and its function to reflect sunlight due to the atmosphere's existence, and there is too much solar energy for simply spacecraft to transport. However, the problem could be solved in two ways. One way is to use the cosmic elevator to bring material to the space station. The only debate on the future of cosmic elevator is whether it could be connected to a rotating planet, yet scientists have no doubt that it could be connected to the relatively stationary space station, for the cost of the program is only one billion dollars, and the material for such infrastructure is abundant. The other way is to excavate silicon, the essential material to build mirrors, on the moon. The strategy is applicable since there is abundant silicon element on the moon to create mirrors covering the equator.

However perfect the approach seems, there is one deficiency- the long time required to bring mirrors from Earth. The mass it can carry is limited, so it would take thousands of rides to bring all crude materials up to space, and each turn also takes much time. While comparing the deficiencies and benefits in the long term, the strategy is highly potential because the elevator would eventually be built, and excavation would also be applicable in the future. The deficiencies are minor, and, most importantly, the solution it offers could resolve the fundamental issue --- the intake of solar energy.

3.2 Exploiting Renewable Resources: A "Green" World

In the recent century, fossil fuel is no longer the single source of energy, and the various alternatives all possess great potential to resolve global warming, yet they are not mature in the current state. Therefore, the future of these new energy sources should be thoroughly evaluated, or else the tragedy of the Chernobyl nuclear disaster might once again occur (in the 1980s, humans did not fully recognize the danger of nuclear energy, leading to substantial natural pollutions, socio-economic losses, and relocation of 336000 local citizens).

First, wind and hydro energy are mediocre, which are currently used worldwide. These two renewable energy resources are similar in their benefits and detriments that

can be analyzed together. Considering natural reserves, these two resources are all abundant on Earth: water occupies 70.8 percent of Earth's surface, and the wind is constantly blowing in every place. These two resources are also clean energy: they do not produce any greenhouse gas. These two dominant benefits, along with many others, make dams and wind turbines very popular in rural regions. However, the detriments are also very problematic: wind turbine's efficiency dramatically depends on the weather, and dams are too expensive for Low Economically developed countries to afford, so citizens would still have to rely on fossil fuel for energy. Thus greenhouse gas would still be released, and the energy balance would still be subjected to threat.

Second, solar energy is highly potential as the sun is a significant source of inexhaustible energy. The evolution of solar power technologies is among the most promising solutions toward traditional energy deficiency and global warming. Given the development of energy storage and conversion technologies, the efficiency of solar power has been continuously increasing, particularly during the past decades, making solar energy a more relevant source in the future. Another reason why people are paying more attention to solar power technology is its potential role in global warming. Specifically, once solar energy realizes its potential and replaces fossil fuel, the concentration of carbon dioxide in the atmosphere would rapidly drop, and less solar energy could be transformed into heat. In this way, the two main passages of energy balance conservation could be controlled, and global warming would be tackled effectively.

Third, as promising as turning to biofuel seems, it is not a realistic solution. It is estimated that America would need two million acres, two times the current area of agricultural land, to grow raw material for biofuels such as corn and wheat to meet the fuel demand of all Americans. Thus, bio-energy would never become mainstream, and all its benefits are outweighed. Geothermal energy could be another renewable resource that can be utilized in the near future. One primary limitation of geothermal energy is its high cost and relatively low efficiency, so large-scale exploitation of geothermal is still in its infancy.

3.3 Anthropocentric Approaches: Education and Policies

This study further discusses anthropocentric approaches to address global warming issues and solutions. These strategies to be considered include explaining the severe issue of global warming in schools and delivering such messages from mainstream politicians. As for environmental education, many schools, colleges, and university provide environment-related classes, and the number of citizens who takes part in environment-concerning organizations has steadily soared in the recent decade. For example, the continuous determination the China Environmental Protection Association (CECA) put in middle school environmental education has resulted in 10102 citizens' attendance at the international environmental protection expo in 2009 held by CECA, which was the most significant number of visitors in the expo's history then. Since 1997, the association was formed, pressed the urgency for Chinese schools to hold environment classes, and helped develop several textbooks. The work was difficult, but after 12 years, the strategy of environmental education finally paid off and produced a firm eventual effect---forming eco-centrists.

Education gradually increases public awareness about environmental protection, which leads to less carbon emission because eco-centrists are less likely to drive private vehicles and would restrict all sorts of desires for the cause. However, education may be time-consuming, and sometimes it does not work despite consistent devotion (individual discipline is hard to enforce). Although it could be an effective way, the uncertainty would render it less reliable. Therefore, education should not be considered the primary strategy; though, it is also required to lower greenhouse gas concentration gradually.

Another anthropocentric element: public policy is effective. Specifically, the law enforces policy in a short period, so individuals or groups are more likely to perform environmental-friendly actions without hesitation. For example, the Chinese national financial department posed a tax of 10 Yuan per ton of fuel in 2009. This act reduced the percentage of carbon emissions by 18.57% at the end of the year. As opposed to education, policymaking is both efficient and effective, yet it would inevitably create externalities. However, the costs should not be considered since the paper is written from the perspective of an eco-centrist and the U.S. Clean Air Act Amendments of 1970 prohibit the use of cost as a basis for determining regulations required to meet air pollution standards.

4 Conclusion

This study investigates the potential value of various methods aiming to resolve global warming issues, particularly from global energy transfer and balance. Although most methods are applicable and could be combined to achieve maximum effectiveness, this study argues that assessing global warming from an energy perspective should be fundamental.

In particular, this study summarizes the mechanisms dominating the warming climate and subsequently proposes and discusses solutions from three categories: engineering, renewable energy, and anthropocentric approaches. The potential application of mirror construction, solar and geothermal energy utilization, and education and policy approaches are specifically discussed. It is suggested that countries should establish more geothermal generators and solar panels with the final purpose of replacing fossil fuels. Besides, the UN could start the program to construct space mirrors and form stricter policies, environmental conservation assemblies should continuously educate citizens, and low economically developed countries must build hydroelectric, wind turbine power stations.

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