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Can a Symbolic Mega-Unit of Radiative Forcing (RF) Improve Understanding and Assessment of Global Warming and of Mitigation Methods Using Albedo Enhancement from Algae, Cloud, and Land (AEfACL)?

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Abstract: By expressing radiative forcing (RF) in a symbolic mega-unit we better communicate, to governing organizations and the public, the extent of global warming (GW) and the potency of mitigation methods while also 'translating' different GW measures to better explain their interrelationship. An easily visualized symbol that has been suggested is the net shading, or mega-unit, of RF of a "standard 1 km^2 cumulus cloud over one day of -25 W/m^2" (ScCd). As defined, ScCd is equal to 600,000 kWh and equivalent to Temporary heat radiation Equivalent Carbon (ThrEC) of 18,400 tons of carbon heat effect, or 67,300 tons of CO_2 and an approximately 0.136 albedo increase, over 1 km^2. Shading over the whole earth caused by clouds is estimated by NASA as -13 W/m^2. The excess of solar radiation or Earth Energy Imbalance (EEI) striking the earth was + 1.12 W/m^2 in mid-2019 and has been continually increasing. Offsetting this requires the creation of additional reflective surfaces equivalent to 22.848 million square kilometers of ScCd. Such an increase could be provided by albedo enhancement from algae on the ocean surface, marine cloud brightening (MCB) or new marine cloud creation, or land area use that rejuvenates salt flats and similar locations (AEfACL). These are potentially politically acceptable and eventually could be achieved at large enough scale to be effective globally.

Keywords: albedo enhancement; artificial upwelling; albedo; ocean fertilization; radiative forcing; global warming; mitigation; climate change; standard cloud; regenerative agriculture

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1. Introduction

Millions of concerned citizens and scientists and engineers are taking steps in their personal choices and work to reduce carbon emissions. Climate conferences throb with concepts and identify massive projects and efforts to get to net zero carbon in companies and a 1.5 °C maximum temperature increase worldwide. However, success in total, prior to resource draining disasters which may halt further efforts, seems extremely unlikely on current paths with current technology, especially given the human disposition towards fossil fuel consumption and fighting the wrong wars.

António Guterres, the Secretary General of the UN [1], at the end of COP 27 in November 2022 said that "Climate chaos is a crisis of biblical proportions. The signs are everywhere. Instead of a burning bush, we face a burning planet". He went on to say that "We need to drastically reduce emissions now—and this is an issue this COP did not address". If even COP 27 cannot address reductions in emissions, we must look to mitigation methods. Extensive albedo enhancement (AE) will slow the heat increase to give us time, and "to have any hope of keeping to 1.5 °C, we need to massively invest in renewables and end our addiction to fossil fuels" [1].

However, we need to 'buy time'. The investment in renewables and technical competence and innovation in climate-related sciences and engineering is accelerating; however, so far it is inadequate. This is demonstrated by the fact that CO_2 levels have now risen since mid-2019 to 421 ppm [2] from an initial 410 ppm. The far more potent methane has increased much faster.

In referring to the USD 100 billion "loss and damage" funding released for vulnerable countries hit hard by climate disasters, Guterres [1] declared that "A fund for loss and damage is essential". But the funds applied to adaptation will be applied inefficiently unless understanding of the essential mitigation is first increased. "(The fund is not)] an answer if the climate crisis washes a small island state off the map—or turns an entire African country to desert. The world still needs a giant leap on climate ambition".

The 'climate ambition' expressed below is a giant leap for mankind that involves the adoption of enough albedo enhancement (AE) activities to buy time for renewable technologies and investments to replace more of the demand for fossil fuels. To be effective, it will require greater comprehension of climate change mitigation possibilities and the cost of achieving their timely application. Ignorance persists and feelings of helplessness in the face of the magnitude of the seemingly impossible climate change correction, is common. There is a lack of defined, potentially and perceptibly successful, known actions to cool the planet in time. This precludes buy-in.

'Buy-in' to the climate battle can be achieved by a focus on easily understood cooling and increased understanding through the simplification of relevant terminology and the description of cost estimates of the implementation of climate mitigations.

The COP 27 presidential summary outcomes [3] stated that "leaders made clear that the climate crisis is a predominant threat to our planet with cross-cutting implications on the stability, safety and sustainability of communities globally". Further, "leaders reiterated that it was time to move from pledges to rapid, robust and impactful implementation". In the Climate Change and Sustainability Communities roundtable, on the subject of finance, the following message was captured: "Scaling up climate finance (is necessary) and improving access to climate finance, and in addition, deploying financing schemes such as debt for climate swaps to help reduce countries debt in exchange for climate action and commitments".

A means for increasing the comprehension and credibility of actionable climate efforts is proposed below. The cool shade from AE via cloud creation or brightening with the newly identified equivalent carbon effect provides initial understanding and measures. The proven carbon equivalent provides credibility and identifies its potency.

This article suggests projects and develops simple measures for the effectiveness of the various projects possible for underdeveloped (and developed) countries. These projects can be assessed, monitored and financed. They will cool locally and globally and can be used to address climate injustice.

Many of the projects suggested can be initiated on a small scale in multiple locations and, as soon as the techniques are fine-tuned, can be expanded internationally.

1.1. Two Paths Less Taken

There are two paths less taken in the long great war against climate change. The four main paths are emission reduction, carbon sequestration, albedo enhancement, and the boosting of the hydrological cycle to convey more latent heat from the land to the depths of the oceans or outer space. The first two have been engaged but are inadequate. Unless we also communicate the potency of albedo enhancement and utilize it, we will lose the war. Utilizing the latent heat portion of the hydrological cycle is similarly required. This article attempts to expose the potential of albedo enhancement (AE) in greatly slowing the heat increase.

1.2. Rationale for the Use of a Mega-Unit of RF

In a world where the truth has frequently become politically instead of scientifically determined, the science and measures of climate change need to be robust against potential mendacity and more easily understood and communicated to deal with the truly existential threat it poses. Rewards must be obvious and adequate for measurable AE and, as explained below, its 'Temporary heat radiation Equivalent Carbon' (ThrEC). Similarly, rewards should be adequate and obvious for carbon emission reduction and long term sequestration. Likewise for medium term biological carbon sequestration, including forest preservation, afforestation and reforestation, soil carbon from regenerative agriculture, or algae and marine snow falling into the dark zone of the ocean. AE provides a measure that can initiate payment for some projects where a sequestration also can be correctly assumed from a few samples.

Current carbon sequestration and emission reduction methods are inadequate and too slow to take effect. Reducing heat levels with AE can give us time to reduce atmospheric carbon. In response to this challenge, the US White House initiated a five-year research program to look at stratospheric and other AE projects [4], and many countries worldwide are similarly looking for manageable solutions.

The measures proposed here, especially that of a Standard cumulus Cloud day (ScCd) and Temporary heat radiation Equivalent Carbon (ThrEC), can quantify efforts to cool the planet and are shown in Figure 1 (albedo enhancement by cloud or land). These measures will also assist in AE project analysis and the measurement and consideration of albedo losses through sea ice melt, as well as those of glacier and snow cover losses that cause heating.

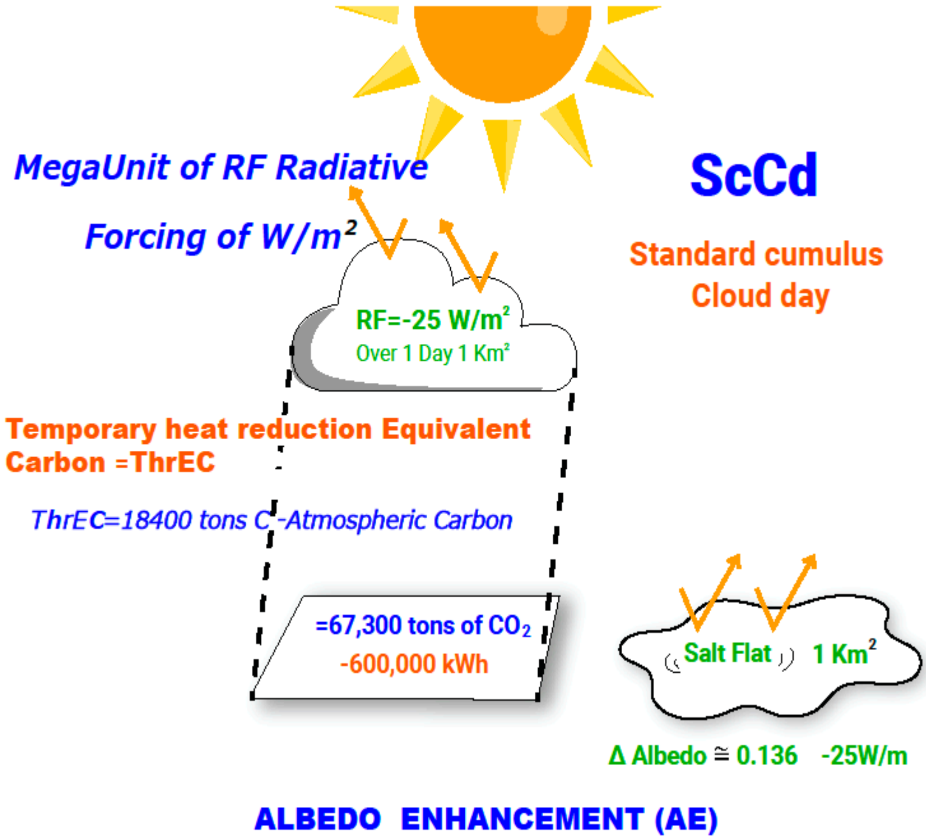

Figure 1. Albedo enhancement (AE) by cloud or by land, such as salt flat rejuvenation. The ScCd cooling effect results in ThrEC and an approximate delta albedo (see Section 1.2 for calculations).

1.3. Rationale for Considering Cloud and Land Albedo Enhancement

Loeb et al. [5] showed, in mid-2019, that the excess of solar radiation or Earth Energy Imbalance (EEI) striking the earth was +1.12 W/m^2 and increasing. The data and examples below illustrate the additional AE required to offset this EEI in various ways.

The National Research Council (NRC) in their comprehensive 2015 study "Climate Intervention: Reflecting Sunlight to Cool Earth" [6] state in their 4th recommendation that "The committee recommends an albedo modification research program be developed and implemented that emphasizes multiple-benefit research that also furthers basic understanding of the climate system and its human dimensions". The measures developed herein should assist such future research and may enable reassessment of past work. Naturally formed clouds play an enormous role in radiative forcing (RF), and, in 2016, NASA [7] calculated cloud shading over the whole earth to be –13 W/m^2.

An example of AE on land is given by Fishman et al. (1994) [8], who studied the meteorological effects of the gypsum at the White Sands National Monument and White Sands Missile range in the USA and found "very significant cooling due to its high albedo". Analysis indicates that the high-albedo surface has a measurable impact on the air temperature within the White Sands area compared with air temperatures from the surrounding missile range. On average, the White Sands area was 1–2 °C cooler than its surroundings during daytime hours in August 1992 and June 1993, and was up to 6 °C cooler at times. This difference in air temperature is attributed mainly to differences in albedo; the dunes have an average measured albedo of 0.60, whereas the surrounding desert areas have an average albedo of 0.20–0.25. On average, the soil (measured at ~1 cm below surface) was 5 °C cooler than that of the surrounding darker area and up to 15 °C cooler at times. No direct correlation between soil temperatures and air temperatures could be established with the available data. This suggests the AE use of gypsum; however, the other multitudinous uses for gypsum raise its value, so lower cost materials are needed to carry out this function in desert and arid lands.

1.4. Rationale for Albedo Enhancement—It Is the Heat

1.4.1. World Land Temperature Increase

The oceans have, since their formation, acted as a moderator of heat over the land. The Berkeley Earth graph (Figure 2) illustrates how land temperatures have increased more quickly since 1960 than those over the ocean. This will accelerate as the land dries, snow cover evaporates, and forests are cleared such that evapotranspiration and evaporation from inland water bodies is reduced and heat shift by latent heat transfer declines [9] (Lightburn K.D. 2024).

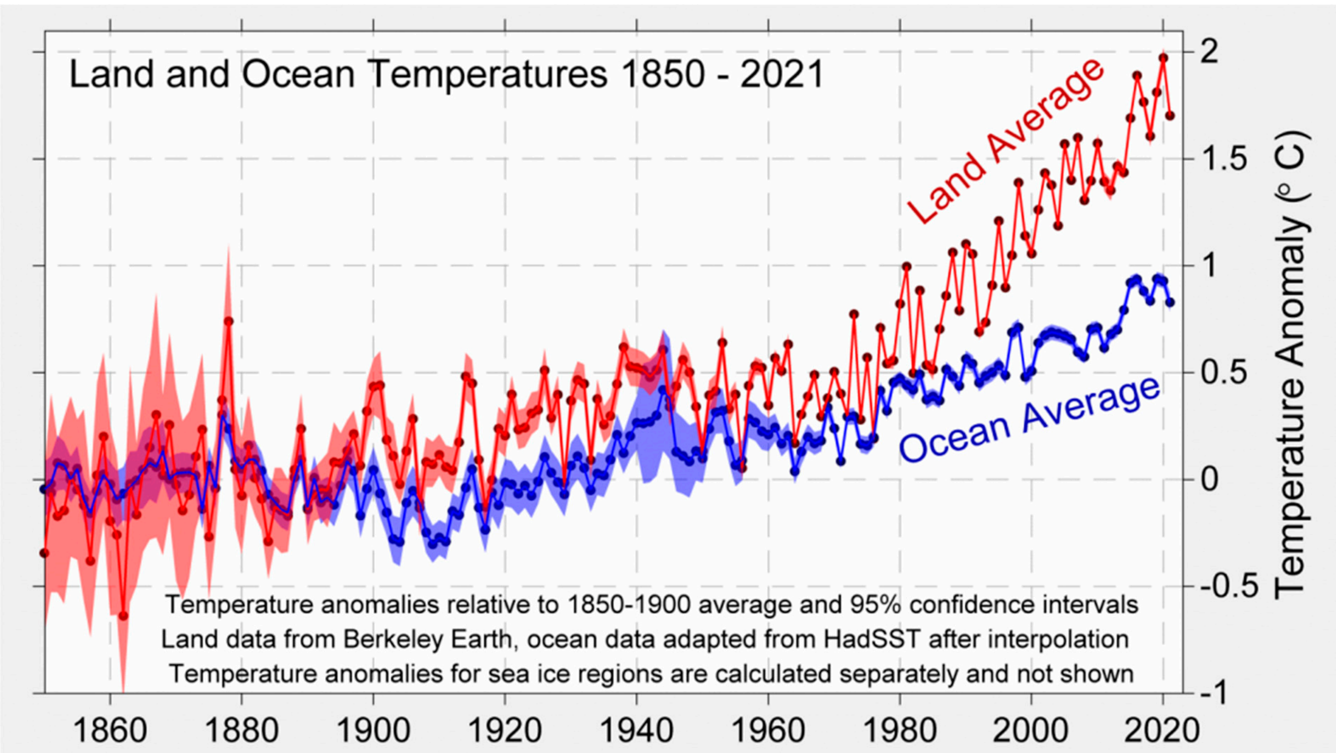

Figure 2. Berkeley Earth graph showing land temperatures increasing faster than ocean temperatures.

1.4.2. Factors Illustrating the Heat Increase

The additional factors pertinent to illustrating the increasing heat are as follows:

- World CO_2 emission reductions of 5% annually will not lower temperature for decades due to climate 'inertia' [10] (Samset et al.).
- The heat extremes kill plants, animals [11] (Bradshaw et al. 2021, "Underestimating the Challenges of Avoiding a Ghastly Future"), and people [12] (Raymond et al. 2020).
- Tropical diseases such as Zika, dengue, chikungunya, and yellow fever (the Aedes-borne viruses) will spread to typically temperate areas as they become warmer [13] (Ryan et al.).
- The globe has warmed by around +1.1 °C. Australia has warmed by around +1.6 °C, a ratio of around 1.4. This suggests that when the world is at 1.5 °C, Australia will be at around +2.1 °C, a trend that has occurred since between 1850 and 1900 a trend that has occurred since a period between 1850 and 1900 [14].
- Temperatures in Antarctica reached record levels during the weekend of 3/19/22, an astonishing 40 °C above normal in places. Weather stations near the North Pole also showed signs of ice melt, with some temperatures 30 °C above normal.

From all these factors we should deduce that heat reduction needs to be a priority. Commitment to large-scale negative radiative forcing is necessary.

1.5. A Standard Cloud as a Measure of Albedo Enhancement (AE)

The cooling effect of a cloud is easily understood. Better understanding of radiative forcing (RF) is possible through the use of this supplementary standard, or mega-unit of RF, as "a standard 1 km^2 cumulus cloud over one day of -25 W/m^2 (ScCd)". Thus, one ScCd is equivalent to RF of -25×1000 m $\times$ 1000 m $\times$ 24 h = $-600{,}000$ kWh/km^2/day (Note 10). ScCd is much easier to visualize than this numerical RF and easier to use in approximating the vast radiative forcings occurring naturally. The potential benefits of radiative forcing through the creation of clouds and equivalent AE on sea or land can be identified.

The Temporary heat radiation Equivalent Carbon (ThrEC) of this standard cloud is calculated by envisaging the whole earth as further shaded to block the 1.12 W/m^2 of excess solar radiation trapped by greenhouse gases (GHG). The weight of all the carbon accumulated in the atmosphere since industrialization to mid-2019 has raised CO_2 concentration from 280 to 410 ppm. This is 1016.3 Gt of CO_2 (Note 1). The other greenhouse gases (GHG) have an equivalent radiative forcing effect of 51.3% of the CO_2, for a total of 1537.5 Gt (Note 2).

1.6. Standard Cloud Carbon Equivalency to Offset the World's Earth Energy Imbalance (EEI)

A total of 1537.5 Gt of carbon could be offset by a sufficient amount of new clouds blocking all EEI, which is specifically 22.848 million sq. km of standard clouds. Thus, one ScCd equates to 67,300 tons of CO_2 heat effect, or 18,400 tons of Temporary heat radiation Equivalent Carbon (ThrEC). [Reduced in scale back to an RF factor of 1 W/m^2, this becomes 0.00851852 g of excess atmospheric carbon in CO_2 equivalent to all GHG per unit] Note 12).

Given these measures, thought leaders, the public, and leaders internationally can better comprehend and support the vast amount of ocean, atmospheric, and desert and arid land research and projects needed. In the short term, the excessive heat is the understood problem, and the cool shade of a cloud is known. On this we can build further understanding. We might say "we can reduce the excessive heat temporarily with enough AE and permanently when we remove the excessive atmospheric carbon".

ThrEC is temporary and only exists for the duration of the AE. The associated temporary AE does, however, reduce the amount of initial accumulated heat (see 600,000 kWh per ScCd in Figure 1). Very simply, an increasingly cloudy world is a cooler world. To become a permanent carbon reduction, it needs to be partnered with equal Negative Emission Technologies (NETs) or renewed perpetually until emissions are reduced sufficiently. The AE keeps the earth cool enough to farm and generate NET.

With the rationale and necessary scope defined, we can now move to the methodology required to achieve a sufficient offset.

2. Methods for Albedo Enhancement

2.1. The Stratospheric Solar Radiation Management (SSRM) Project Is Not Yet Accepted

The Stratospheric Controlled Perturbation Experiment (SCoPEx), or Space umbrella Project, that is under investigation by Harvard University has run into resistance regarding even a test flight of an empty balloon in the stratosphere, even though it had no particles available to release [15] (Sandahl 2021). It was also evaluated by the NRC [6] in 2015, with the recommendation that it not be deployed at that time.

However, SSRM is possibly the least expensive AE project, where particles are injected into the stratosphere to reflect sunlight before it hits the top of the atmosphere (TOA). One early estimate was only US $2.2 billion per annum. Since then, Reynolds further suggested an estimate that included the cost of security that would be needed, which raised the total to US $4 billion [16]. However, Surprise [17] argues that "solar geoengineering (SSRM) is defined by equally compelling 'logics of militarization'", and he further aims to "ground recent conceptions of 'planetary sovereignty' in the emergent field of 'geopolitical ecology' through the latter's more granular approach to the world-making powers of key geopolitical-ecological actors". This article aligns with 'geopolitical ecology' by enhancing natural and reversible processes such as new cloud formation, and these processes have durability for the long great war.

2.2. SSRM Hurdles

The cessation of this project (say due to war or attacks on the planes or balloons dispersing the particles due to severe disagreements with the project) would lead to a sudden increase in heat if the CO_2 had continued to accumulate [18] (Jones et al. 2013). If SO_2 is used, as was first planned, then the ozone hole would expand in size [19] (Kravitz et al. 2020). Calcium carbonate ($CaCO_3$) is now considered a more suitable medium, although more expensive. Weather changes would be different for different countries and perhaps not all would welcome it. It is not manageable as the winds in the stratosphere will spread any particles throughout the stratosphere. A drier China and wetter India was one forecast.

Despite all the negative possible side effects, the SSRM project may be carried out in the absence of understood and proven alternatives, such as albedo enhancement from algae, cloud, and land (AEfACL). This could be triggered by desperation resulting from storms, ocean levels rising, and forced migration associated with temperature increases, crop failures, and ecological degradation occurring as we approach the 1.5C targeted maximum and likely exceed it.

2.3. Albedo Enhancement from Algae, Cloud, and Land (AEfACL)

Equal areas of surface algae, salt flat rejuvenation (or land-based AE), and marine cloud brightening (shown in Figure 3) can all generate temporary atmospheric carbon reduction equivalence.

By estimating various climate project values, we can begin to identify suitable research targets.

Most of the following AE methods are possibly much more expensive but more politically acceptable as they can be carried out by many countries, with some producing food and being capable of control. They need to be modeled and researched vigorously to evaluate the best locations for the different AEfACL methods whilst prototypes of the equipment to carry them out are developed.

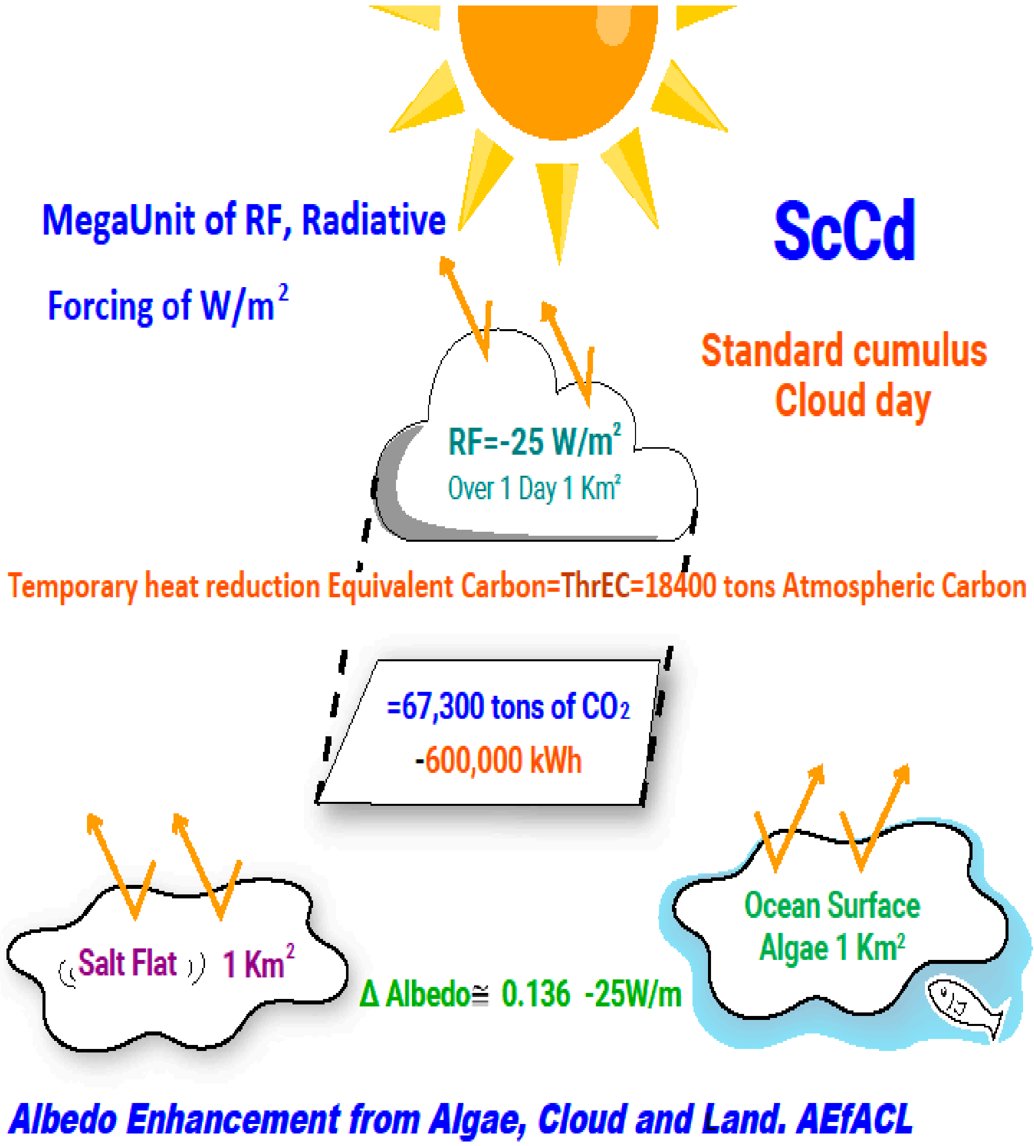

Figure 3. Estimating AE values from land (such as salt flats), marine cloud brightening (MCB), or near-surface algae creation (AEfACL).

2.3.1. Marine Cloud Brightening (MCB)

MCB has been extensively studied since Latham's identification of this opportunity [20–24], with immense engineering expertise applied to possible salt particle dispersion [25]. However, recent work has suggested that a focus on particle size for Cloud Condensing Nuclei (CCN) is necessary [26,27]. On a preliminary basis, this seems to initially favor dimethyl sulfide (DMS) rather than salt particles, particularly as the AE of both algae and clouds can be obtained through fertilization, while salt particles can only realize the AE of clouds. However, DMS also has weaknesses. A study by Novak et al. [27] indicated that DMS was better at new cloud formation than the AE of existing clouds. This last work, however, was not carried out where vast densities of DMS might be created by fertilization. Timely research is required. Given the critical value of cloud information, we need extensive drone data collection and much more time in 'flying laboratories' to further the work carried out by Novak et al. [27].

2.3.2. Artificial Upwelling (AU) and/or Ocean Fertilization (OF)

AU and OF are truly multifunctional and can also provide carbon sequestration while providing AE [28] (Pan et al. 2015). They can oxygenate dead zones in the ocean (e.g., near river outflows such as the Mississippi), generate AE in the form of a reflective surface of algae, and produce DMS gas both as a byproduct and as the algae decomposes. This provides excellent CCN for cloud formation and brightening (MCB) [28–30]. It will also provide a heat sink to the ocean depths for land heat transfer as part of the hydrological cycle, and especially sequesters carbon as phytoplankton (or their decomposing remains) sink towards the ocean floor. If we look hard here, we will value and pursue temporary sequestration in the dark zone.

The cooler surface water from AU can reduce hurricane strength if strategically placed. Perhaps 10 to 100,000 units in the Gulf of Mexico would curtail the strength of several hurricanes. Algae blooms from the raised nutrients would boost fish production and tourism.

Overall, AU and/or OF reduces the ocean temperature due to the radiation reflected and the carbon sequestered. If sufficiently vast, algae reflection of solar radiation alone would suffice to offset EEI (Note 5). In 1965, the use of reflective objects floating on the ocean was first proposed by the President's Science Advisory Committee as a solution and is now under consideration again by a current President's Advisory Committee [31] (Hornig et al., 1965). They will undoubtedly consider algae. The need to perfect artificial upwelling (AU) devices and test their combination with ocean fertilization in various environments and sites is equally urgent.

Strong et al. (2009) [32], after an examination of iron fertilization research spanning two decades, argue that "we know enough about ocean fertilization to say that it should not be considered further as a means to mitigate climate change. But, ocean fertilization research should not be halted: if used appropriately and applied to testable hypotheses, it is a powerful research tool for understanding the responses of ocean ecosystems in the context of climate change." However, our current state of urgency invokes consideration of the temporary sequestration of carbon in the dark zone and temporary AE from algae on the ocean surface; thus, ocean fertilization should be looked at anew. An increase in albedo of only RF 1.6 W/m^2 over all the world's oceans alone would offset the 2019 EEI [5] (Loeb et al.) in total (Note 11).

2.3.3. Land Surfaces Such as Salt Flats with AE

Salt flats can be very valuable if sustained permanently or until atmospheric CO_2 is reduced sufficiently, i.e., effectively matched to emission reduction. For example, endorheic lakes below sea level in 17 sites around the world have a total area of 65,000 km^2 [9] (Lightburn 2024) and thus provide areas where salt flat management and rejuvenation can be carried out. There are also somewhat similar areas at slightly higher levels that are capable of salt flat activation, which may very conservatively total five times as much area (total of 5 $\times$ 65,000 = 325,000 sq. km).

If this was activated, on average, by a factor of 1.0 ScCd for every sq. km, then we have 325,000 ScCd worth of radiation forcing, which is equal to 325,000 $\times$ 18,400 $\times$ \$100/ton, or a value of US \$598 trillion at US \$100 per ton if permanently renewed. This is still only 325,000/22,840,000, or 1.4% of the total needed.

Utilizing parts of the area of the Great Salt Lake in Utah, and enhancing the albedo of the nearby salt flats and adding to them, would lower temperatures locally and slow evaporation of the remaining water, thus prolonging its life. Its current projected demise is to a dust bowl of toxins [33] (Milman 2023). AE experiments there with atmospheric analysis would be appreciated and productive. Highly saline water with an otherwise low value could be used to boost albedo through flood and dry methods. It would also further reduce lake evaporation slightly by raising the humidity.

One 1000 sq. km Salt Flat Example

AE of one endorheic lake salt flat of only 1000 sq. km by 0.136 albedo (or -25 W/m^2) would generate ThrEC of 18.4 $\times$ 10^6 tons. If permanent, at US \$100 per ton, the value would be US \$1.840 $\times$ 10^6. However, this can only become equivalent to permanent carbon if renewed perpetually or partnered with Negative Emission Technology (NET). It would then yield US $1,840,000,000 in climate benefits. These numbers illustrate the potential of AE, but what would be the cost of activating the project? The same 1000 sq. km of salt flats, if earning only US $0.01 for each temporary or ThrEC ton day, would yield US $18,400,000/100 = US $184,000 per day if it had an AE of 1 ScCd per sq. km, though higher AE per km^2 is possible. As some governments are willing to pay US $100 per ton and more for permanent carbon capture and sequestration, perhaps one government, philanthropist, or company will consider US $0.01 per ThrEC ton for activation.

Total Area Required

The small percentage (1.4%) resulting from these significant efforts on salt flat land, relative to the whole area of AE required, emphasizes the enormity of the task. Thus, there is a need to urgently begin experiments in places such as the Great Salt Lake in Utah, the Badwater Basin in California, Lake Eyre in South Australia, and the Qattara Depression in Egypt to optimize salt flat rejuvenation techniques that are easy to prolong. The benefits of extending AE projects onto arid land with nontoxic reflective material would be demonstrated.

Furthermore, an urgent look at other land surface treatments is needed. Regenerative farming on fertile land [34] (Gilchrist et al. 2021) and the vast amount of arid or desert land awaits our efforts and creativity.

AE can help sustain food production by cooling land temperatures. This AE, and any partnered NET project costs, can correctly be regarded as the cost of emissions, as can the costs of all mitigation plans.

2.4. *Albedo Enhancement Farming (AEF) and Regenerative Agriculture—Value Demonstration*

Planted cover crops can reflect sunlight better than plowed soil and generate radiative forcing [35] (Davin et al.). The high value of an AEF crop can encourage farmers to contribute to worldwide AE and is demonstrated below.

Results from the White Sands National Monument [8] (Fishman et al.) indicate that setting up 1 sq. km of land in an arid area with the same white gypsum, if compared to the same adjacent land albedo, would have an albedo enhancement of 0.35 (0.6–0.25 for the adjacent arid land). This would yield an ScCd of 3.822, ThrEC per day of 47,398 tons of carbon, and annual ThrEC of 47,398 $\times$ 365 days $\times$ US $0.1 = US $1,730,042 at a ThrEC ton per day price of US$0.10, i.e., only ten cents.

This is US $7004 per acre per annum, or US $17,300 per hectare, illustrating the potency of AE in comparison to other carbon capture and sequestration projects. It is not a big step to regard gypsum as almost permanent rather than temporary, and therefore capable of yielding a 47,398 ton carbon payout at a much higher value than the US $0.1 per ton.

2.4.1. New Values of Prior Land Use Analysis

To the government payee, a more palatable result would arise from albedo enhancement of crops, fallow crop land, or cover crops (Davin et al.) [35], or from new forest using albedo enhancing initiating surrounds, leaf types, or agricultural cover crops. Swantson et al. [36] call for "Adaptation through the maintenance and enhancement of genetic diversity". This might include more reflective leaves, such as the cold-temperature Eucalypts with their reflective leaves and moisture retentive properties for boreal forest areas. Carrer et al. (2018) [37] measured albedo-induced radiative forcing throughout Europe for a three-month cover crop. In over 28 countries, the results ranged from -1.04 W/m^2 (in Spain) to -8.74 W/m^2 (in Poland), with an average of -1.49 W/m^2.

Using a 'temporary carbon' measure of ThreC at only USD 10 per Ton year or only USD 10/365x100 = USD 2.74 per ton-100 days, i.e., USD 0.0274 per ton day, we find: On a per hectare basis, this becomes an average of USD 30.05 per hectare for average Europe; USD 20.97 per hectare for Spain; and USD 176.25 for Poland. On a per acre basis, this becomes USD 12.16 for Europe on average, USD 8.49 for Spain and USD 71.33 for Poland (In the EU, normal long-term carbon credits are about USD 96 per ton in 2023). In the likely event of more El Nino-driven stronger heat waves, these prices may soon appear too low to incentivize enough farmers to convert to maintaining cover crops in this regenerative agriculture. In a similar way, the local and continental cooling produced by this AE can be calculated using the ScCd data and equivalents. In addition to this, in effect by timed release (as demanded naturally when heat waves strike), the latent heat cooling from additional retained moisture of these cover crops can easily exceed that through albedo enhancement [9].

2.4.2. Regenerative Farming Is a Project Naturally Partnered with NET

So even if we begin at US $0.01 to $0.1 per ThrEC ton, it may provoke extra effort in terms of farming ground cover and the funding of irrigation and thus change farming practices towards more regenerative farming. In doing so, we build adaptive practices to deal with heat waves by using the additional stored moisture in the soil. The additional CO_2 sequestered by the ground cover is also demonstrated (Carrer et al.) [37] and adds value. This is indeed a partnering of NET of the extra soil carbon generated with a portion of the ground cover AE-created ThrEC, and so has a double yield and value for this regenerative agriculture.

2.5. Partnering with Negative Emission Technologies (NETs) by any AE Project

Partnering of AE with NET has the benefit of association with the planet-cooling AE protecting the carbon sequestration plantation, wherever and whatever its form.

The ThrEC heat reflection effect carbon equivalent has different levels of permanency, making possible partnering complex. Reynolds [16] suggested that the SSRM project be partnered fully with massive emission reductions, though this would be difficult to administer. Perhaps this partnering would be easier with smaller projects, such as those below. Clouds of short-term duration can be paid on a new ThrEC-only scale. Alternatively, they can be fully valued when fully partnered with an NET to earn a portion of the total, which perhaps is only a small fraction (say 1–5%) that is dependent on the duration and their carbon sequestration comparison.

AE of salt flats or desert or arid land albedo covering can be sustained if the operatives have functional access and sufficient incentive. Thus, these are worthy of a higher share of the partnered NET, perhaps 5% to 50% of the total payout.

Some potential Negative Emission Technology (NET) partners for AE, which would make the ThrEC 'permanent' if they could be activated adequately in a timely fashion, are described below.

NETs with potential include:

1. Preferred above all, the cutting of emissions in a select project (but emissions are increasing overall).
2. Afforestation and reforestation, the preservation of forested areas, and the planting of new forests. However, the potential is limited in the USA [38] according to Gorte (2015). However, Gorte's work could bear reappraisal considering the vigorous planting of faster growing trees more suited to the warming Arctic, which could be evaluated and developed in the USA before then being applied worldwide, including eventually in Siberia in a peaceful Russia. Preferably the species selected would protect areas of snow cover from melting and/or utilize thawed permafrost. Betts (2000) [39] models and weighs the increase in boreal forest plantations against the loss of snow-covered land.
3. As well as albedo enhancement, the vital part played by trees in 'moisture sequestration' by their roots and shade in the hydrological cycle, as well as in moving heat from the land to the sea or space, needs further evaluation [40] (McElrone et al.) [9] (Lightburn 2024).
4. Afforestation is paralleled in the ocean by kelp farming, with the kelp dropped into the ocean depths to sequester the carbon.

5. Regenerative agriculture [34] (Gilchrist et al. 2021) [41] (White 2018): Additional carbon is retained in the soil along with additional moisture. This helps deal with heat waves as the reserved moisture, and therefore latent heat, is released through evapotranspiration [42] (van der Linden et al. 2019) [34] (Gilchrist 2021), thereby cooling the surroundings. Such pastures are therefore more drought-resistant. They also produce AE and ThrEC carbon partnered with additional (NET) soil carbon.
6. Biochar [43] (Van Beilen 2016) [44] (Buss et al. 2020): farm waste burned without oxygen and buried boosts sequestration and plant nutrition but is limited by fuel availability and cost. Perhaps macroalgae washed ashore would provide a useful new source and income. It has been used in the past for fertilizer without being burnt.
7. Ocean fertilization or artificial upwelling (AU) captures carbon in the ocean in algal blooms and through some sinking to the ocean depths. A meta-study by Keating-Bitoni (2022) states that ocean fertilization alone is not sufficient for significant carbon sequestration [45]: "On average, studies show that approximately 10% of phytoplankton organic carbon matter settles from the sunlight zone to the dark zone; of that 10%, possibly less than 1% is buried in ocean sediments". However, that 10% remaining in the dark zone is effectively a temporary sequestration from the atmosphere and has the potential to be recycled by natural or artificial upwelling, thus later yielding surface algae for AE purposes or the growth of more storable carbon, such as perhaps kelp or sea grasses or seaweed. Even by residing in the dark zone, part of this carbon has been removed temporarily from the atmosphere. The value of temporary sequestration needs recognition when dealing with the short-term aspects of the crisis.
8. Direct Air Capture (DAC) mechanically and chemically extracts CO_2 and makes it available for storage [46]. Izikowitz (2021) discusses the need for "20 million of the present state of the art 50 ton/year modules to deliver 1 gigaton per year", which so far has proven to be far too expensive.
9. Bioenergy with Carbon Capture and Storage (BECCS) is the process of extracting bioenergy from biomass and capturing and storing the carbon. In total, potentially 0 to 22 Gt per year has been identified, though this is constrained by biomass availability and cost [47] (Smith and Porter 2018). Again, shore-stranded, previously floating, perhaps fertilized, and AE generating macroalgae, once dried out, may provide a new source. Salt residues would need to be addressed. Such projects could be investigated for the Caribbean islands when they are inundated with huge tonnages of Sargasso seaweed.

2.6. One Existing Large NET Project

In an example to the world, Pakistan has planted one billion trees and has a project to plant nine billion more. It is financially supported by the German government through a German bank (KfW Development Bank of Germany). That project could sequester 0.04 Gigaton of carbon) [48] (Hutt, 2021). This is 40,000,000 tons of carbon and worth US $4 billion dollars at US $100/ton. It also unfortunately illustrates the slow speed and necessary scale of one of the best human endeavors to sequester carbon and its limitations, thus demonstrating the need for AE. However, further value lies in the additional moisture retention and latent heat circulation provided through the boosted hydrological cycle [9] (Lightburn 2024).

In the same way, inland bodies of water provide latent heat removal of land heat into space (see the total 80 W/m^2 on Figure A1) and into the ocean depths. (As the hydrological cycle is also vital to cooling the land, we should seriously consider leaving dams in the northwest of the US and elsewhere. Fish migration would then have to occur with bypass constructs if they are now sufficiently effective, or the newly spawned fish would eventually be at risk of dying in the overheated waters of the streams.)

2.7. Albedo Enhancement Is Essential

Ocean fertilization on a massive scale would be the fastest and cheapest ocean manipulation to carry out to begin the temperature decrease we need. It does not involve the massive cost and construction of artificial upwelling equipment pieces that would perhaps eventually number in the millions. Thus, ocean fertilization might best be initiated first. However, extensive modeling and research, as well as action, are urgently necessary:

- There is no longer time to cut emissions sufficiently to stop faster temperature increases, especially over land.
- The Stratospheric Solar Radiation Management (SSRM) concept has not been acceptable for much of the scientific community, though it is now being researched anew by a task force initiated by the White House in a 5-year analysis [4]. In an act of desperation, a country may actuate the SSRM project prematurely.
- Salt flat AE will offer a measure of climate justice along with significant cooling effects. Parallel usage of high-albedo materials or compounds on arid land can yield high ScCd values and high durability while improving crop prospects.
- MCB when appropriately located has the advantage of potentially reducing ice melt and snow cover reductions through cooling while at the same time directly reducing the impact of shortwave radiation.
- Moore et al. (2019) [49] examined the effect of SSRM on Greenland ice melt and stated that, due to the threat of sea level rise, "How Greenland would respond is a key factor in deciding the potential utility of doing geoengineering (SSRM)". The same models applied to AEfACL created nearby would produce useful information.

2.8. AE Projects Deserving Early Consideration

2.8.1. AE Payments Would Encourage Private Industries to Partner with Governments

Barron et al. [50] found that even a very low carbon tax would begin to yield results. In the same way, even an incentive of only US $0.01 per ThrEC ton would yield US $18.4/ScCd, as 18,400 tons of ThrEC are generated per ScCd. Even at that low level, this may lead to the initiation of some of the less expensive projects and encourage entrepreneurial activity, thus beginning to define new AE possibilities.

2.8.2. AE on Deserts and Arid Land

Deserts and arid land can contribute to, and begin to yield a measure of, climate justice through payments for rejuvenated salt flats or 'albedo farming' with other surface modifiers. In Egypt, the Qattara Depression alone covers an area of 20,000 sq. km, and much of it may be suitable for salt flat development. Block (2017) [51] believes that revitalization of Qanats could have a very significant effect from the AE generated.

Vast deserts and arid lands may yield very significant long term AE results through the use of appropriate technology, such as the fine nozzle spray devised for MCB that creates small crystals or particles. Alternatively, suitable particles may be mined and ground. These may be of olivine ($MgFeSiO_3$) [52] (Fuhr et al.) or limestone compounds, gypsum, or some other material; however, it must have higher albedo than the soil or desert sand it is replacing. Its durability will help determine its economic value.

Gypsum, such as that at the White Sands National Monument, was reported [8] as having an albedo of 0.6, thus providing local air- and soil-cooling effects. A fine powder which can blow and spread naturally over areas and remain on top of the sand would be suitable. Further desirable requirements include materials that do not degrade ground water in the process of weathering and more fertile soil. Weathering of the olivine in the arid lands may significantly sequester carbon with occasional rain as it can do in the ocean, except faster as it is not 'buffered' by the salts in sea water when doing so [52] (Fuhr et al. 2022).

If it was possible to activate vast reaches of the Gobi, Sahara, and similar deserts and arid land with reflective particles, then a significant portion of the 22.848 million km^2 needed may be 'farmed' for RF. This 'crop' can have significant financial value. The actual radiation striking the desert is much higher than the 'average' figures due to the typically clear skies and RF will thus be higher. Underground habitats for the 'farmers' will be needed to take advantage of the cooler conditions there so as to make the conditions tolerable, and RF 'farming' could occur at night or in the cooler portions of the day in a warming world.

Caliche on the surface can capture and sequester carbon dioxide and form caliche beds under the sand where rainfall is adequate.

Funding for desert and arid land AE might come from oil-rich Middle Eastern countries as there will be local cooling benefits besides global benefits.

Can our highly innovative glass manufacturers develop a 'soft glass' suitable for AE in the desert in its waste form after serving as holding vessels? The potential of normal recycled glass is to form sand with blasting effects too potent for desert inhabitants or equipment. Additionally, very fine glass sand particles would fall through the courser sand and not 'present' to provide AE. There is a huge reward to be obtained for the inventor of new vessel materials suitable for AE in its waste form. Perhaps reverse engineering is called for.

2.8.3. AE on the Ocean and Lakes

The advantage of combining ocean fertilization and artificial upwelling is the combination of surface AE for algal blooms and cloud formation from the algae-emitted DMS gas in the atmosphere. In addition, both contribute to carbon sequestration through the formation of 'marine snow' and algae falling towards the deep ocean floor. Even the temporary sequestration of carbon in the dark zone has value. Carbon sequestration and AE go hand in hand. Satellite measurement of albedo change would provide some measure of results but may have to be supplemented with measurement by drones.

The application of either or both AU and ocean fertilization to selected areas will determine the rapidity and extent of the results. In the Southern Ocean, some 47 researchers (Blain et al.) [53] have reported that "We found that a large phytoplankton bloom over the Kerguelen plateau in the Southern Ocean was sustained by the supply of iron and major nutrients to surface waters from iron-rich deep water below. The efficiency of fertilization, defined as the ratio of the carbon export to the amount of iron supplied, was at least ten times higher than previous estimates from short-term blooms induced by iron-addition experiments". In the same way, we would expect that artificial upwelling or downwelling, when coupled with surface fertilization, would boost the total phytoplankton bloom quantity for both AE and sequestration, with [28] Pan et al. (2015) stating that "Thus, artificial upwelling has the potential to succeed as a geoengineering technique to sequester anthropogenic CO_2, with appropriate technical parameters in the right region and season". Yao et al. (2020) [54] state that "one of major obstacles for the large-scale field application of artificial upwelling is the dilution of uplifted nutrient-rich water in density-stratified ocean". Furthermore, McCoy et al. (2015) [55] correlated MODIS cloud properties over the Southern Ocean with various biogenic aerosol proxies and found that variations in aerosols derived from organic sources explain a large fraction, approximately 50%, of the variation in cloud droplet number inferred. It follows that if we could identify such natural upwellings from, for example, surface temperature anomalies or preliminary algal blooms, that adding fertilizer may produce the best and fastest results most economically [56] (Oschlies et al.).

Lakes have potential and can be thought of as miniature seas with better control but more NIMBY problems (not in my back yard).

2.8.4. Aquaculture Leases to Cause AE

The aquaculture industry may contribute as follows: If optimization of artificial upwelling and ocean fertilization was first selected to seek results from AE, then it could be initiated with the declaration of many more aquaculture leases (nine new areas were recently allowed for the USA) in the dead zones in the Gulf of Mexico and similar international areas proximate to freshwater inflows in other salt water bodies. Aquaculturists would be incentivized to oxygenate the water, produce algae, and start the process while at the same time reducing hurricane strength and generating food. If the culture of the seaweed Asparagopsis can be mastered profitably for such sites, then it can be provided for cattle, as 1% of Asparagopsis in their food stops methane belching. A total of 111 tons per day is sufficient for the dairy cattle in California [57] (Lightburn 2024), so obviously the market is vast; the value can also be assumed to be high for meat and milk products sold to conscientious consumers. However, artificial bromoforms are already being produced by an Australian company (Rumin8), so shellfish or crustaceans would probably be more profitable. Shellfish in the tropics can capture huge amounts of CO_2 (28 tons per hectare of shell weight from giant clams) [57].

2.8.5. Wind Farms and Artificial Upwelling

Artificial upwelling when used in conjunction with wind farms has synergistic effects [57], with greater wind farm efficiency and greater upwelling efficiency.

2.9. Urban Cooling

White roofs have a multiplier cooling effect as they reduce the need for air conditioning and the flow of hot air into the streets, otherwise boosting the heat island effect (Pearl S. 2019) [58].

3. Discussion

3.1. Communicating for Broader Comprehension

3.1.1. Communication of Climate Change Factors

To many scientists, it is taboo to consider albedo enhancement, SSRM, or Solar Radiation Management in any form as it may divert resources and research away from increased 1000-year sequestration and the decreasing of emissions. Furthermore, they see it being used to provide an excuse for further fossil fuel production and consumption by consumers and industry.

However, the extent of the albedo enhancement needed to deal with even the 2019 Earth Energy Imbalance (EEI) of 1.12 W/m^2 (namely 22.8 million km^2 of ScCd or its equivalent), once understood, highlights the extent of the problem, which is compounded by the trending increase [5] (Loeb et al.). When supplemented by estimates of the effect of high-albedo surface losses, evidence accumulates that we are fast running out of time and opportunities for AE to provide a brief respite so that we can get our carbon 'house' in order and reduce emissions.

Furthermore, since some of the AE methods recommended also cause sequestration and food production, they should be favored over SSRM. As mentioned below, AE, when properly quantified, can also help model and predict a tipping point in relation to the loss of sufficient snow and similar cover.

The main problem with SSRM is the multitudinous risks associated. It would be cheaper to activate but the consequences could be very expensive, and imagined or real unwanted weather patterns would be blamed on it, with perhaps violent responses. It may still be needed if we do not take adequate alternative mitigation actions in time; therefore, it must also be researched.

3.1.2. Visualizing Large-Scale Activity

When contemplating one ScCd (equal to 2.16×10^{12} watts per km^2 per day), the increased ability to visualize this amount of energy reflected or absorbed and, further, that of sufficient cloud to block the Earth Energy Imbalance of 1.12 W/m^2 (namely 22.848 million km^2, or 2.3 times the area of the USA with Alaska and Hawaii included) becomes possible. The same visualization does not occur in watts at $22.848 \times 10^6 \times 2.16 \times 10^{12} = 493.5 \times 10^{18}$ watts/day.

The numbers are so vast when dealing with climate change on a global scale that we need bigger and preferably symbolic units to make them understandable. Politicians and the public cannot be expected to understand and react dramatically to the threat to humanity of the apparently 'tiny' 1.12 W/m^2 EEI (Earth Energy Imbalance) [5] (Loeb et al.), so we need a different language or representation. The need for 22.848 million km^2 of new clouds of one ScCd per km^2 strength to block this tiny but worldwide wattage can be understood by high school students. Comprehension of not only the cost of damage but also the cost of offsetting our fossil fuel consumption, with AE or otherwise, would follow.

The ScCd equivalents provide a 'translation' measure, including that of RF in W/m^2, as represented by ScCd with its 600,000 kWh/km^2/day, the Temporary heat radiation Equivalent Carbon (ThrEC) of atmospheric carbon, and GHG equivalents. ThrEC is 18,400 tons of carbon for the total GHG equivalents. Atmospheric equivalent carbon dioxide and GHG represented as CO_2 can be measured at 67,300 tons, and a crude but useful estimate of the albedo change equivalent to an ScCd of 0.136 [Note 6 and Figure A1]. It thus better indicates areas for further research and will provide an understandable measure of their success. These figures and ratios are based on mid-2019 data, and the standard will alter slightly over time with changes in the percentage of other highly potent GHG such as methane and, possibly, accumulation levels.

3.2. Which Albedo Enhancement Project to Start?

3.2.1. Ocean Fertilization and Artificial Upwelling

The least expensive, most economical, and fastest return in cloud creation and algae reflection with temporary carbon sequestration would be expected from ocean fertilization in the Southern Ocean [55] (McCoy et al.) [56] (Oschlies et al.) [59] (Evans et al. 2018). However, conditions are prohibitive, and it would be difficult to carry out. Climate modeling and knowledge of ocean nutrient content and currents will assist in site selection internationally and seasonally. Such other areas may yield more urgently required climate benefits. China, with its vast fishing fleets and food need, is likely to support or even initiate such activities, whereas it may not support SSRM, especially if it increases drought in China. The political argument for it could be that, otherwise, SSRM is necessary. This is probably real.

A great deal of research has been conducted on artificial upwelling. Valuable studies by [28] Pan et al. (2015), [60] Zhou et al. (2019), and many others have been made in China and elsewhere. Once modeled and proven experimentally, the least expensive way may be to use iron ore transport ships directly from the ore export port (eventually remotely controlled) to take the mined ore, grind it on board, and disperse it. This would minimize handling costs, and perhaps existing vessels could be successfully modified for dispersion in the Southern Ocean. However, even in the summer, using far less than a full load would probably be necessary for safety reasons. Seasonally, dispersion in the northern hemisphere's Arctic summer may yield algae and clouds to shade and reduce glacial and ice sheet melting, as well as assist with excess heat globally [9].

3.2.2. Saving Barrier Reefs

Salvation of barrier reefs is a critical factor globally, and the benefits of artificial upwelling and this cold deep water flowing over the reefs is indicated by a preliminary study in Barbados in 2020 [61] (Sawall 2020) where intermittent cool deep water was used to mitigate heat stress in laboratory samples. Such AU would also cool the air with sensible heat transfer from deep ocean water, AE from surface algae reflection, and AE from DMS-produced clouds.

If artificial upwelling (AU and AD) is further indicated, then a 'war' effort will be called for to produce and distribute enough units and would need to follow quickly behind ocean fertilization efforts, where it might result in oxygen depletion. Free-floating units in various gyres should be considered, as tethering units in stormy deep waters will be impossible. A recent OpenBook sweeping review of artificial upwelling [62] (National Academies 2022) highlights the possibilities and risks.

3.2.3. Macroalgae or Seaweed Farming

Macroalgae in the form of kelp farms or areas can contribute through satellite- or drone-collected albedo values and provide estimates of the effect of future efforts as the top of the kelp often lays on the surface. Such farms are, of necessity, in protected waters and not yet sufficiently vast. The Sargasso Sea could yield AE values to indicate potential, particularly for the area within 5 degrees S to 25 degrees N and 89 degrees W to 15 degrees E for the duration of 2018, and especially for the period April 2018 to August 2018, when it was at significant density. If Sargasso seaweed proved to be significantly reflective in its semi-submerged state, fertilization and transplantation would be justified to optimize its range and proximity to the surface.

3.2.4. Single-Cell Algae

However, single-cell algae species will probably provide the best solution for the vast areas needed, and they do not impede fishing fleets. Identification of suitable algae is a challenging task. A single-cell healthy alga (not red tide) with a propensity to float to the surface and bloom through the aid of inexpensive fertilizers would be valuable and might be used as an inoculum in the fertilization process so as to supplement the natural algae produced.

3.2.5. Considerations for Ocean Fertilization

As a recent reminder, a February 2023 article [63] (Ripple et al.) listed ice and snow melt as two of several tipping points after which, on reaching certain levels, a return to the prior status of the earth could not be realized, thus potentially rendering some correction activities impossible. Thus, an urgent call to action on all possible AE fronts, including ocean iron fertilization (OIF), is appropriate. Some of the disadvantages of OIF (or any form of ocean fertilization (OF)) to overcome are mentioned below with suggested solutions.

Decades of work on ocean fertilization has cast doubt on some of its potential. Some supporting arguments are put forward here for its reinstatement as a geoengineering mega weapon for mitigation and sequestration.

Algal Selection, Research, and Propagation

In the immediate and distant future, a critical yet incredibly difficult task is to learn to continuously use the huge 'canvas' of the ocean surface for AE, DMS production, and carbon sequestration whilst improving its health and fish production.

The disadvantages of simply adding any fertilizer (e.g., iron ore finely ground) to the ocean include that it may aid the growth of toxic algae, which could be especially harmful in coastal waters [64] (Anderson et al. 2023). Risk minimization could be improved by initially only fertilizing very lightly over huge areas of open ocean. This will result in a large variety of species, with less chance of one becoming dominant and toxic. Different initial algae 'stocks' with varying nutritional and environmental factors will favor different species. A further measure may be inoculation, alongside fertilizer, with healthy algae that have the potential to dominate. This would add to the cost but may be economically viable, especially long term due to high ScCd values being desirable.

Approximately 25% of the oceans have inadequate iron but an adequate amount of other nutrients. The Redfield ratio, expressed as '106C:16N:1 P; 0.001 Fe', signifies that, in iron-deficient conditions, each atom of iron can fix 106,000 atoms of carbon [65] (Sundra et al. 1995), or, on a mass basis, each kg of iron can fix 83,000 kg of carbon dioxide.

Thus, even after doubts regarding sufficient impact and its validity in earning carbon credits, many exacting prior studies should be looked at anew. There is increased potential for a renewed perspective on the highly diffuse spreading of a fine iron ore dust in irondepleted areas. This arises, in part, due to the new overview allowed by the measure of ThrEC for AE of the ocean or clouds.

Furthermore, one of the expressed concerns about OIF is that the total ocean production of algae would not increase but instead, this would be negated by its higher value when that algae occurs at or on the surface. In addition, this is further negated by selection of more productive (in AE or DMS terms) algal species and 'ranching', as well as by the eventual use of AU on a huge scale to move nutrients to the surface waters, thus supplementing ocean fertilization.

Tropospheric Release of Iron Chloride

An interesting variation regarding the activation of AE with iron fertilization was suggested by Oeste et al. (2017) [66]. They suggested using ferrous chloride salts as a dust introduced to the troposphere to mimic iron dust particles already in the atmosphere that are blown there by wind from mostly desert areas. Its beauty lies in its ability to pull methane out of the atmosphere, as well as performing other AE functions. Methane with GHG other than CO_2 causes 34% of the radiative forcing of all GHG [Note 2], and methane represents approximately 16% of the total. This effect alone could be dramatic. They suggest it could stop global warming and even reverse it. Lifting a large portion of the 0.3 Tg of Fe required into the troposphere might be expensive but worth it in the troubled Arctic regions.

Propagate or Perish

Just as we have used seed selection and propagation in agriculture for thousands of years, we can apply the same principles (accelerated and enabled by algal high reproduction rates) to algal selection and propagation in the oceans. We could perhaps follow the fertilizing ship(s) with research vessels to seek the ideal algal species. Those with maximum surface albedo and surface durability will be obvious. Drones could even monitor DMS ahead of and perhaps behind the research vessel after the algae had time to begin to decay. Drones ahead of the fertilizer ship could establish a baseline of existing DMS and AE. Satellites may provide further data to include cloud AE changes (an expensive project, though, once selected, suitable species of algae could be provided to many countries for release and fertilization, perhaps near their fresh water nutrient rich outflows).

The lag time selected to trail the fertilization could be monitored by drones from the research ship. In the tropical Caribbean, at St. Croix Island, the average doubling time over an extended period was 8 h for a local naturally occurring species of single-cell algae in the additional nutrient-rich water provided by AU. The research focused on shellfish aquaculture using artificial upwelling and was organized by Columbia University's Lamont–Doherty laboratory [67] (Lightburn 1972). Thus, algae in the tropics may become much more visible on or near to the surface after only a few days, and drone monitoring from the following research vessel could identify its location, extent, AE, and DMS levels.

Toxic algae will frequently tend to emerge as their nature restricts their consumption by some other organisms and warming oceans provide new environments [68] (Anderson et al. 2021). For this reason, a constant program of non-toxic algae inoculation with the fertilizer may, over time, have to evolve. (This might be useful in the Arctic regions mentioned so as to dominate the toxic algae and protect the food supplies there).

Seeking to control toxic algal blooms on the open ocean with, for example, clay, as was mentioned in the Woods Hole paper [64] for shoreline shellfish salvation, is not possible. Instead, for the wide ocean, a focus on sources of good algal blooms and identification of ways to best selectively propagate them as a control mechanism is suitable. Given the inadequate climate tipping point avoidance time probably available [63], a focus on whichever algae do well in different specific environments and seasons is required. Those selected might be further studied in the laboratory for doubling rates with a variety of affordable nutrient mix variants.

Coccolithophores

Perhaps there is a very narrow range of nutrients that best supports the algae that produce ocean surface AE or cloud AE.

If we were looking to optimize DMS production for cloud formation, then dimethylsulfoniopropionate (DMSP), the precursor of DMS, is significantly produced by coccolithophores. Again, limestone fertilization may be worth considering as it could accompany the natu-ral or artificial production of coccolithophores [68] (Keller1989), and these are producers of the precursor of DMS, which acts as an excellent CCN for cloud AE to accompany their apparently excellent carbon sequestration function.

The promise of coccolithophores [69] (Rost and Reibesell 2004) as part of a carbon capture and sequestration process is exciting if we can economically supply replacements for the calcium consumed from the upper surface waters by the coccolithophores. Iron fertilization thus needs supplementation with limestone or a similar calcium fertilizer, otherwise more acidic sea water results from their growth. Individually, the dimpled spherical coccolithophores appear to be tiny bombs of captured carbon that are designed to head all the way to the deep ocean floor. Limestone, or similar, may be from the same ship or proceed or lag iron fertilization to optimize benefits and water de-acidification and health.

Marine aquaculture companies and laboratories could be contracted to mass propagate suitable algae species selected from the ocean and isolated at sea from prolific blooms using research vessels.

When ocean-supplied artificial desert lakes (OSaDL) [57] are developed, they could also serve to culture vast tonnages of specific algae; however, there is always the potential, in an open system, of a collapse of the culture and takeover by another perhaps unwanted species that may have arrived, literally, on the last strong breeze. Thus, perhaps culture of several mixed species would be more stable in that nutrients from the collapse of one species would be taken up by another in planned sequential blooms.

Although eventually requiring a significant ongoing expense, the results can be measured with existing instruments and technology and guidance from experienced personnel, with methods modified, expanded, and contracted based on results. Use of some transport vessels or cruise ships, with monitors on board, should be considered as they are simple means for distribution. Their marine transport carbon footprint and perhaps more may be offset and even add to their revenue with the sale of carbon credits generated by ThreC and sequestration. Certainly even experimental use could add to their image and help educate their passengers so commercial participation should be possible to achieve. The time for the sole use of scientific research vessels may be past.

3.2.6. Island Nations

Island nations with adequate harbors provide a base for numerous AE activities, beginning with AU to protect reefs and moving to the management of thousands of AU units, ocean fertilization, and aquaculture. All could be financed by the US $100 billion and more promised by the COP, as the developed nations would also benefit.

3.3. Why Act Now?

Desertification, sea ice melt, glacier melt, and snow cover loss are not long-term problems, they are immediate. They magnify GHG effects, so EEI and temperature effects will be far worse than a linear relationship to atmospheric GHG. Therefore, we must consider short-term carbon removal solutions as well as the 1000-year sequestration ideal. The timeliness of such action is critical, as permanent loss of reflective surfaces such as snow cover needs to be replaced by new alternative AE to maintain the existing Earth Energy Imbalance (EEI) and resist its further increase. Unless there is associated sufficient natural new cloud formation and latent heat cooling to substitute, we may get a 'hockey stick' rise in EEI readings to add to that of temperature [70] (Osman et al. 2021); we would then be describing a severe and perhaps catastrophic tipping point. Monitoring and expressing AE levels locally or by continent may become as significant as monitoring CO_2 levels globally in providing an understanding of climate change.

If we permanently lost snow cover (or snow cover previously shaded and protected) provided by the now occasionally burning boreal forests, of an amount equal in ScCd to 22.848 million sq. km, then we might expect EEI to double to 2.24 W/m^2. Approximately, the rate of temperature increase would then double. This needs urgent modeling and research in view of its tipping point identification potential. The albedo of snow is 0.8–0.9 when fresh, and, as such, its albedo is approximately three times that of land. Therefore, the total area required is only 22.848/3 = 7.6 million sq. km of snow loss to produce this effect. Siberia is 13.1 million sq. km, so we need to raise awareness and take appropriate action in all pertinent dimensions, from research to political action.

3.4. Can you Imagine All the Cooling?

Can you imagine an amazing world where China, the USA, the EU, and eventually Russia form an alliance to wage war on climate change, a war of global existential value? Can you imagine it happening before we trigger a tipping point, destroying populations and cultures and triggering unjust wars everywhere? Might such an alliance be considered as an alternative to SSRM, or will tardiness ensure it has to be additional?

3.5. To Pay, How Much to Pay?

That is the Question–Whether tis nobler in the mind to suffer
The Storms and droughts of outrageous climate,
Or to Enhance Albedo against a sea of troubles,
And, by offsetting, ease them?

Determining and obtaining acceptance of a suitable payment initiated by private enterprise and perhaps later taken over by governments would be effective. Starting at even US $0.01 (one cent) per ThrEC ton may help initiate and suggest a course forward. It took years before carbon credit trading was approved by the UN [71] (Charles 2021). Trading in ThrEC credits should be encouraged, thus causing the development of AE technology to accelerate. Spreading calcium carbonate or other reflective materials on dry land, where salt is undesirable due to soil contamination, is essential to slow desertification. Ming et al. (2014) [72] also examined the possibilities of enhancing long wave (LW) radiation techniques to cool the earth. Suitable ThrEC estimates for LW radiation could be identified (Section 3.6.2 below) and used to further evaluate those projects.

Arid lands have an advantage over deserts for AE work in that a compound used first for reflection but also capable of reacting with rain and CO_2 such that it will sequester the carbon underground (olivine) [53] (Fuhr et al.), or more likely limestone, can then support some plant growth, retain more moisture due to the shading of the soil, and promote growth through the upward reflection of light onto the growing plant. Deserts, on the other hand, have an advantage over arid lands in that their atmosphere is clearer, with greater quantities of short-wave radiation available to reflect any AE activities into space; thus, larger ThrEC effects per sq. km would occur.

Value and payment can be based on ThrEC values from the satellite- and drone-monitored AE results of projects. This is far easier to measure than soil carbon increase. These projects may make effective use of arid or desert land, ocean or lake waters, and clouds in developing countries, with project financing provided by developed countries. Payees also will benefit. Developed countries would be more willing and speedy in forwarding the already promised USD 100 billion for climate remediation, which would be followed by more if they saw it applied to AE projects with globally as well as locally measurable benefits.

Temporary carbon sequestration is worthy of energetic pursuit in both its actual carbon form and its heat equivalent form, as well as a reward system with a clear difference made between it and permanent carbon sequestration with 1000-year potential. Three types of carbon sequestration and effect need recognition and reward. The need for multiple duration graduation values for the two temporary carbons becomes apparent.

Three Types of Carbon Sequestration of Varying Duration

(1) "Sequestered Forever Carbon" consisting of carbon extracted and captured and sequestered securely in rock formations miles underground.

(2) "Temporary Bioformed Carbon", such as algae sinking into the dark zone of the ocean with probably many years before currents move it to natural upwelling areas, thus bringing it to the surface again. Also included are forests and regenerative farming to replace regular farming.

(3) "ThrEC Carbon" is Temporary heat radiation Equivalent Carbon, and its value depends on the duration of the AE that offsets the radiation.

Each type needs its own pay scale, earning possibilities, incentives, governance, and evaluation standards. The time value of sequestration provides a useful concept for evaluation, especially recognition of the value of even short-term sequestration.

3.6. Possible Other Uses of the GasMass = RF Equivalency

The ThrEC calculations were made based on a single time point of data (mid-2019) and EEI based on a summation of many heat fluxes and radiative forcings (Figure A1). Will this approximation hold for other times and environments? Can we obtain multiple other data points for excess CO_2 above the 280 ppm level?

3.6.1. Different Constant for Total GHG

A different constant would result if we used the total GHG equivalent in CO_2. The initial constant was calculated for a narrow set of environmental conditions using a particular EEI level; however, if a linear relationship holds, and if we can take it further, this total GHG constant will approximately be the ratio of the ppm of CO_2, i.e., 410/130 = 3.154 times as great, or 0.00851852 $\times$ 3.154 = 0.026867 g of carbon GHG equivalent in total in the atmosphere for each equivalent CO_2 generated net W/m^2. However, this approximation does not allow for the lower ratio of other GHG to total CO_2. Where do we find data points to adjust, disprove, or validate this? If validated as an approximation, then this equation may then be of value in further interpretation of historic and prehistoric values and trends in temperatures and atmospheric variables.

3.6.2. Long-Wave Radiation and Low-Grade Heat?

Can it logically and usefully be applied or adapted or equated in any way to long-wave radiation alone? Superficially, it appears the value of enhanced long-wave radiation could be similarly equated to ThrEC after taking into account the different energy levels of SW and LW radiation. Can it be applied to low-grade heat generated by our steel, cement, and glass factories, as well as all factories down to the energy consumption of households?

The consumption of renewable energy may not have a net carbon output, but it will generate heat in a crowding world, and this too must eventually be offset or moved off-world in some way.

One ScCd reflects 600,000 kWh of heat; however, unless heat is reflected back into space to boost earth's natural heat removal, we need to employ the thermal bridges and the thermal window projects comprehensively listed by Ming et al. [72] to move it to the upper atmosphere and into space.

3.7. Carbon Credits?

Huge corporations and government departments desire to be carbon neutral and set time-critical targets before then finding that some of their carbon generation is incredibly expensive and difficult to remove. They then seek to purchase scarce carbon credits to offset them. When good governance and assessment for AEfACL projects is in place and

ThrEC carbon trading acceptable, value-determined, and activated, then vast resources from these organizations will accelerate all carbon offset programs.

3.8. Is Snow Melt or Sea Ice Loss Cause for Concern?

Unless snow melt or sea ice melt is offset by additional natural cloud formation or the associated latent heat transfer, we need man-made albedo enhancement to offset the global snow cover and sea ice decrease.

The above analysis points to the prospect of massive losses in albedo from snow melt on land becoming a trigger point for an unacceptable rate of heat increase. This possible eventual initiation of an out-of-control warming rate would earn the title of tipping point. Such a possibility should activate an increased interest in measurement and albedo.

3.9. Perception of Activated Weather-Influencing Methods

Whether imagined or the real effect of weather modification methods, any bad weather occurring after activation will be blamed on the process by individuals and countries, even if the real alternative was catastrophic. Buy-in to the concepts with prior-modeled, small-scale, gradually expanded, cooling, or food-yielding projects with visible and model-proved positive results are more likely from AEfACL than SSRM, and thus can gain acceptance for further use in the long great war.

4. Conclusions

Bradshaw et al. [11] state that "The scale of the threats to the biosphere and all its lifeforms-including humanity–is in fact so great that it is difficult to grasp for even well-informed experts". This is further challenged by the need to understand and compare the multiple productive activities possible. This article has defined common measurement to accelerate communication and to identify the potential benefits of AE through its measure of temporary carbon. AE can similarly apply understanding to the downside of albedo loss and further explain the extent and cost of global warming.

4.1. Evolving Hypotheses Resolved

The title of this article is the initial hypothesis. Climate change 'buy-in' can be more broadly achieved by simplifying the factors expressing climate. The poor worldwide performance in reducing emissions was initially due to the incredible economics of fossil fuels. However, with cheaper renewables it is now, in part, due to a poor comprehension of, or disconnect from, the climate crisis. In other words, a lack of 'buy-in'. Correction is possible with a focus on cooling, as allowed by the nature of AE, rather than invisible CO_2 and other GHG. Initiated here as a means to measure and prove the value of MCB with salt particles, ScCd emerged, and logic steered the search for a solution in other fruitful directions.

The mega-unit approach further moves the discourse from ScCd to visualizing the EEI offset worldwide with sufficient ScCd strength in clouds, algae, and land. Thus, the measure of Temporary heat radiation Equivalent Carbon (ThrEC) was found. Temporary carbon equivalency provides new credibility for AE. The value of contemplating other temporary solutions to sequestration is also emphasized. Highly durable ThrEC is near permanent, and thus does not need an NET partner in order to be assigned significant value.

The expansion of quantitative descriptions and the comparison of various AE projects was possible with this measure of AE and temporary carbon. In addition, a first approximation of the potential replacement of SSRM with scalable, more politically acceptable, and reversible AEfACL projects emerged. Multitudinous examples of AEfACL projects, with a first estimate of benefits, provide target areas for various communities to consider, act on, or support.

The conclusion is that buying time with AE so that renewables can adequately replace fossil fuel consumption looks possible if the scientific community, thought leaders, corporations, and governments support this approach and bend our scarcest resource, human capital, to its pursuit.

4.2. Communication Improved

Communication between scientists, engineers, governments, and the no-longer trusting climate reality-divided general population can be improved through the use of this additional symbolic standard and its derivatives. The disconnect from climate can be overcome through comprehension of the heat effect of clouds. Even a smart ninth grader can feel the cooling effects of a cloud, relate it to a learnt understanding of cloud albedo, and teach their parents. Besides assisting creativity and the identification of new solutions, understanding can yield hope (such as the hope identified as critically needed by Hayhoe (2021) [73] in thinking about the threats of global warming (GW)) and thus further encourage the pursuit and support of productive solutions.

Perhaps more importantly, it helps quantify the magnitude of the problem and the price of correction to our fossil fuel consumption. The cost of the offsetting AE projects is one of the costs of excess emissions.

4.3. Two Paths Worth Taking

There are two paths less taken in the long great war against climate change. Four of the main paths are emission reduction, carbon sequestration, albedo enhancement, and the boosting of the hydrological cycle to convey more latent heat from the land to the depths of the oceans or outer space. The first two have been engaged but are inadequate and tardy relative to the extent of the accumulated GHG and the acceleration of EEI [5]. If we can further expose the potency of albedo enhancement and quickly move to utilize it, while also doing so for the latent heat portion of the hydrological cycle [9,57] (Lightburn 2024), we will win the war. Forest preservation, afforestation and reforestation [36] (Swanston et al., 2016), and regenerative farming [34] (Gilchrist 2021) will play large roles on this last path, along with precipitation and, later, evaporation from the new cloud formations.

4.4. Two Sets of Projects Using Albedo to Cool the World

Stratospheric Solar Radiation Management (SSRM) needs to be researched and planned so it can be activated if it ever becomes essential. However, its use is suggested only as a last resort after more controllable and reversible projects, such as albedo enhancement from algae, cloud and land (AEfACL), have been researched, optimized, and activated.

If preceded by modeling and experiments to identify algae, sites, fertilizer selection, and distribution means, then massive AE and sequestration synergism could be achieved. The initial creation of a vast reflective ocean-shading algae surface could be followed by constant decay to yield further DMS production, resulting in new cloud formation and MCB. At the same time, temporary sequestration of 10% of the algal carbon into the dark zone [45] (Keating-Bitoni 2022) would occur. This may yield preliminary results economically and encourage further AEfACL activities.

Huge quantities of algae grown in the oceans are used for food, and with output and consumption growing rapidly, this combines with AE effects so that we gain further.

Although perhaps ten-fold more expensive than SSRM when fully operational in the sites selected to yield the best results (such as near the Arctic, Antarctic polar, and Greenland ice melt), AEfACL can be activated by many countries. Added benefits include more fish in the ocean, the protection of farming from temperature extremes on land, and the sequestering of carbon in the deep sea. Activated desert and arid land salt flats and ground cover will lower local temperatures enough for more crops. AEfACL could even provide a rescue by replacing the functions of the widely opposed SSRM project if it was activated prematurely by an errant country. Thus, if AEfACL were initiated much earlier, it would expand and take over the offset function of SSRM if it was shut down for any reason. It will, however, take a great deal of time to fully activate AEfACL in appropriate sites with adequate techniques.

The concept and quantity of 18,400 tons of temporary carbon (ThrEC) being equal to a measure of radiant heat (1 ScCd) or RF of $-25\ W/m^2$ over 1 km^2 for one day illustrates not only the enormous potential of creating AE, but also the risk of losing albedo anywhere on the globe. It also provides a tool that may be applied to other atmospheric phenomena.

The Secretary General of the United Nations declared that [1] "It will take each and every one of us fighting in the trenches each and every day. Together, let's not relent in the fight for climate justice and climate ambition. We can and must win this battle for our lives. The world still needs a giant leap in climate ambition". The use of AEfACL worldwide is one way to apply our ambition with an evident chance of success. Perhaps the High Seas Treaty [74] (Stallard E.), newly agreed after a decade of negotiations, will lend a framework for the criteria, determination, activation and supervision of such a plan for the oceans while individual countries are assessing the possibility and extent of their participation in the Treaty.

Many peoples and countries, if financed, can use AE projects on water, land, and air to reduce excessive heat. Emission quantities are most significant in developed countries, so only the efforts of major developed countries and manufacturers to reduce their emissions is of adequate global significance initially. It will only take comprehension and incentives to initiate many viable AE projects. Payments by developed countries made to underdeveloped countries can activate these measurable AE projects, thus offering a thousand possible stepping stones to climate justice and yielding time to reduce our emissions.

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Appendix A

Note 1.

The total mass of air in the atmosphere is 5136×10^{12} tons [75] (Lide 1996). CO_2 levels in mid-2019 were 410 ppm (Global Monitoring Laboratories), and prior to the industrial age they were 280 ppm, so we have an additional 130 ppm by volume. By mass this is

$0.0130\ V\% \times (44.095/28.97) = 0.0197872$ extra mass percentage.

where molar mass CO_2 = 44.0095 g/mole and the mean molar mass of air = 28.97 g/mole

Thus, extra CO_2 mass is $0.0197872/100 \times 5136 \times 10^{12}$ tons = 1016.3 gigatons of CO_2.

Note 2.

Radiative Forcing Caused by Major Long-Lived Greenhouse Gases 1979–2019 (EPA's Climate Change indicators) [76] c2es (2021).

Units: watts per square meter. Ratios

Table A1. Radiative Forcing.

Year	Carbon	Methane	Nitrous	CFC-12	CFC-11	15 Other	Total Other	TOTAL	Percent
	Dioxide		Oxide			Gases	GHG	with CO_2	Total/CO_2
2019	2.076	0.516	0.202	0.161	0.057	0.129	1.065	3.141	1.513

Note 3.

There is decreasing albedo due to sea ice loss and more soot on the snow from the Arctic to Siberia since the mid-2019 data used, and the Arctic is warming nearly four times as fast as global temperatures [77] (Rantanen 2022). Notionally, the standard cloud ScCd yields a cloud-enveloped effect (AsCRA) that will need to be larger as GW progresses. The accuracy of measurements of the additional EEI is increasing, and so is the amount of EEI [3]. Although Trenberth [78] noted that EEI was far lower than the trend in 2020, a more recent article suggests that huge amounts of smoke from the Australian mega-fires that rose into the stratosphere may have caused this [79] (D'Angelo et al. 2022).

Note 4.

Using a crude estimate, if we assume one artificial upwelling unit delivers 1 ton/s of water yielding to the surface and an available sensible heat change of 1 degree of cover in one day, the cooling possible is $3600 \times 24 \times 1000 \times 1 \times 4.18$ kJ = $3600 \times 24 \times 4.18 \times 10^6$ kJ or $3600 \times 24 \times 4.18 \times 10^6/3600 = 24 \times 4180$ = kWh. This equates to only 100,320/600,000 = 0.1672 of an ScCd. Thus, we need an estimated 6 units of this capacity to equate the cooling of one ScCd. Other much more theoretically efficient but untested units are covered elsewhere [57] (Lightburn 2024).

Note 5.

If we consider the top 1 m of a square kilometer of sea water as having no mixing or evaporation change, then the cooling effect of surface algae (or cloud) for 1 ScCd would be as follows: From the diagram of albedo enhancement, 1 ScCd over 1 sq. km per day is 600,000 kWh over each sq. km; thus, each 1 sq. m = 600 watt hours = 600 joules per second $\times$ 60 $\times$ 60 per day. It takes 4186 joules to heat 1 kg of water by 1 degree C. Thus, each ton of water, if fresh, would lose $600 \times 60 \times 60$ joules per day of energy, or $600 \times 60 \times 60/4186/1000$ degrees C = 0.516. For a cubic meter of sea water with a density of 1.03 and a specific heat of 1.047, it would be cooled by $0.516/1.047 \times 1.03$ = *0.51* degrees C.

Note 6.

The average albedo for the earth from the top of the atmosphere (TOA) is estimated to be about 0.3 according to a NASA document (NASA 2014) [5]; however, this includes reflection from clouds and soot and atmospheric particles. If we assume a clear sky without the dust particles [80] (Haywood et al. 2005), then, from the Global Energy Balance diagram, we see that of the 161 + 23 = 184 W/m^2 hitting the earth itself below the atmosphere, 23 W/m^2 is shown as reflected, giving a below-atmosphere albedo (BAA) earth average of 23/184 = 0.125. Thus, if any surface albedo is increased by a factor of 0.136 for a Km^2, it would on average produce -25 W/m^2 of additional albedo (0.136 = 25/184) and be equivalent to a standard cloud effect (ScCd). However, these are average figures for the earth and local effects can be much greater (Note 8) and vary with the season and time of day.

Below: Sunlight coming to Earth is on the left. Infrared radiation going away from Earth is on the right. (Image: K. Trenberth, J. Fasullo, and J. Kiehl) Downloaded 19 August 2021, UCAR Center for Science Education.

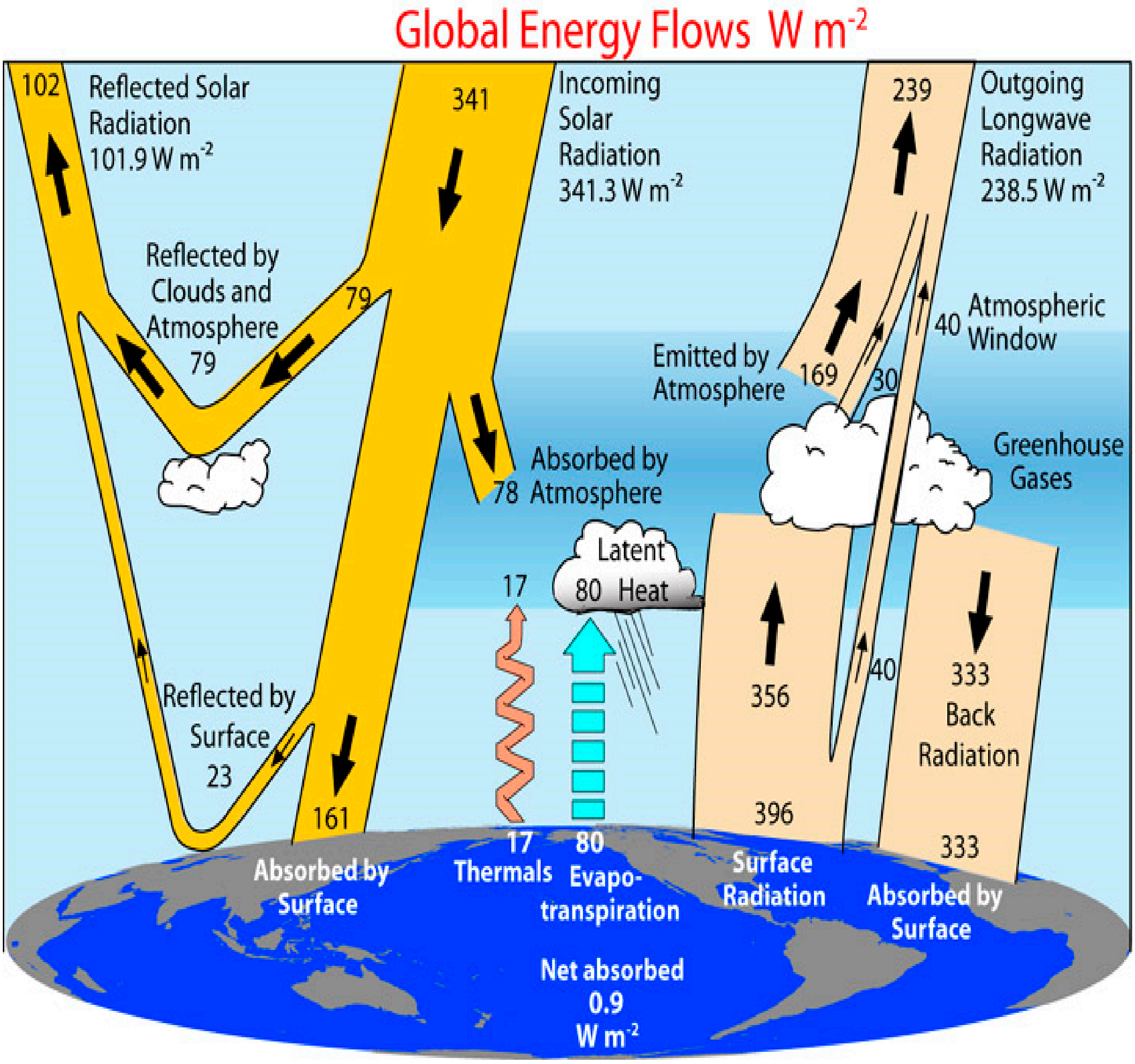

Figure A1. Global Energy Flows.

Note 7.

The Badwater Basin in California would provide a test area for evaluating albedo enhancement with occasional flooding of artesian water, and a parallel operation with a salt flat such as Lake Eyre in South Australia or the Qattara Depression in Egypt would provide data for a more typical desert salt flat without the high mountains surrounding it.

Note 8.

"Except during periods of dust storms, the desert atmosphere is very clear, clouds are a rare occurrence, and the water vapor is very low. During the day, the incoming flux of solar energy approached a maximum for the latitude and time of year. Approximately 80% of solar radiation at the top of the atmosphere reaches the surface" [81] (Oke).

Note 9.

Algae area required: The area of 1 ScCd required to stop EEI of 1.12 W/m^2 is 22.848 million square kilometers. If that is not at RF -25 w/m^2, then doubling the area would require half as much at -12.5 W/m^2. A quarter delta 0.034 or 25/4 W/m^2 = -6.25 W/m^2 would require four times that area, or 4 × 22.848 = 91.4 million sq. km. Blain et al. (2007) [53] reported a natural boost of -10 W/m^2 over parts of the southern ocean during summer. Nonetheless, this is an enormous task, so we may need selected species of algae to boost the AE. Sargasso seaweed has small air bubbles trapped that keep it near the surface and may have value. It could probably not be selected for or modified to a white color as some freshwater algae are, as that would reduce its energy uptake and growth, but it is worth consideration and experiment.

Note 10.

ScCd is equivalent to RF of −25 W/m^2. So, for a km^2 it is equal to 1000 m × 1000 m, and for a day × 24 h = −600,000 kWh/km^2/day. If expressed in W/km^2/day, it becomes a cumulative 600,000,000 watts × 60 s × 60 min = 2160 × 1,000,000,000 W/km^2/day.

Note 11.

In total, 71% of the world is the area of oceans × 1.6 W/m^2 = 1.12 W/m^2 (EEI) over the entire area of the globe.

Note 12.

RF of 1 W/m^2 is equivalent to ThrEC of 0.00851852 g. EXCESS CO_2 is calculated as follows:

1 ScCd is equivalent to 600,000 Kwh and ThrEC of 18400 tons of carbon equivalent over 1 Sq. km day with an RF of −25 W/m^2.

600,000 kWh = 600,000 × 60 × 60 × 1000 = 2.16 × 10^{12} W/km^2/day.

equivalent to 18400 tons/km^2/day at RF-25.

equivalent to 18.4 kg/sq. m/day at RF-25.

equivalent to 0.000212963 Kg/s of ThrEC/sq. m/s/25RF.

equivalent to 0.212963 g/s of ThrEC/sq. m/s/RF25.

equivalent to 0.00851852 g of ThrEC/sq. m/s/RF = 1 w/s.

Thus, we have 0.00851852 g of excess GHG =1 W/m^2 Or EEI with an RF of 1 W/m^2 = 0.00851852 g of excess GHG in ThrEC terms.

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