4 What ought to be done? (Complete article)

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Summary

Are there any alternatives to reversing global heating apart from by cutting down on CO_2 emissions? Are there ways of getting rid of already emitted CO_2? Is it possible to produce more electricity without extended transmission? This article discusses some options.

Different methods of cooling the planet exist. All using heat emittance to universe. Because of possible risks these methods have fallen in disrepute in the science community and IPCC has thus been hesitant. However, new interests are emerging while the 1.5 – 2 degrees goal seems more difficult to reach. Could these methods be considered after all?

I have investigated two methods. Their cooling potential, practical concerns, costs, and risks involved. The first involves new material that emits heat through the CO_2 in the air. Day and night, keeping cool even in sunlight. An additional advantage is the condensation capability, producing water. The second uses light microspheres, like fine sand, floating on water, increasing the reflectance, or albedo, and bouncing back sunlight and heat to universe.

Daylight radiating and albedo increase needs large spaces to have a global effect. Deserts, abandoned crop fields, small lakes/ponds in the tundra and even parts of forests could be used. Albedo increasing microspheres could be used at sea, on lakes and on boglands.

This article is about finding needed space and methods of applying emitting and reflecting material. Emitting material could be sprayed thinly on parts of barren land. Film could be used also utilizing the condensation capability. Microspheres could be spread by boats.

Growing trees is the least costly way of soaking up CO_2. A trillion trees can be planted until all land have run out. Enhanced weathering, dissolving minerals, have the potential to soak up all excess CO_2. Both are inexpensive but need a long time to work. More than hundred years. The methods can´t help the urgent need for cooling but can help ridding CO_2 in time.

More sustainably produced electricity is needed. Solar panels + batteries could soon be the least costly alternative. I believe that new incentives are needed to speed up installations.

I believe the wealthy population´s potential of 360 billion US $/year might cool the planet, generate large amounts of freshwater, mitigate emissions, reduce a god bit of CO_2 from the atmosphere and facilitate a lot of local electric power – all in parallel, in a decade or two.

To get things going fast, I suggest decentralized implementation along with new financial incentives. All working in parallel around the planet.

Introduction

My son asked me a few years ago, knowing I am a climate optimist, about my view of the scalability of the voluntary efforts I do. If there would be enough mitigation projects if billions of people would buy offsets and if a small monthly sum from each one of them would have any significant effect on the global temperature. A very relevant question that I couldn´t answer.

I am now, after private research for some time, quite hopeful that 1,5 billion people paying 20 US $/ month could fix the climate together and, in this article, I describe how I believe it could work out. It is a compilation of ideas, that needs further development and research of course. And based on what 360 billion US $/year from the wealthy could finance.

Reducing the level of CO2 is no quick fix

All possible solutions, I have been able to find, meant to reverse global overheating involves a lot of capital, large scale global implementations, long timespans, and risks.

Most large-scale mitigations in use are of the sort that slow down further increase of CO2. Biofuels, electric cars, electric generation by solar and wind are well known examples.

Most methods, with a few exceptions, that take CO2 out of the air are still experimental, resource consuming and not effective enough to reverse temperature increase in a foreseeable future. As many as 30.000 Direct Air Capture (DAC)[1] machines might be needed just to take away the annual addition of about 40GT CO2/year. That number of removal-machines would also consume over half of the available energy used today on the planet or about a quarter of all estimated energy year 2100. As one example.

Methods that take the temperature down on a global scale, independently of the level of CO2, are still, mostly futuristic, not researched enough and have so far been regarded too risky. Vailing[2] a method of cooling the planet through sun-reflecting aerosols sprayed from airplanes is perhaps the most discussed and most criticized idea of so-called geoengineering, because of possible risks.

Apart from vailing, marine cloud brightening has also been a discussed favorite. It involves saltwater being sprayed into clouds making them whiter. There are theories of changing genes in crops to make them brighter. There has been talks of huge mirrors in the space reflecting sunlight and there are ideas of creating reflecting bubbles on the surface of the oceans. As a few examples. All meant to reflect heat away from earth. Most methods also rely on new technologies being developed and methods that must be used in large scale and all the time for a foreseeable future to get wanted effect.

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[1] Evans S. (2019) *Direct CO2 capture machines could use a quarter of global energy in 2100* Accessed September 11, 2021, from https://www.carbonbrief.org/direct-co2-capture-machines-could-use-quarter-global-energy-in-2100

[2] Robock (2016) *Albedo enhancement by stratospheric sulfur injections: More research is needed Accessed* September 11, 2021, from https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016EF000407

Why has solar geoengineering not taken off?

An important topic discussed among policymakers and researchers, that effects possible implementation of cooling measures, concerns decision over temperature setting. If you can lower the global temperature, how much should you lower it and where, how would you handle the risks, and who decides. A summary of possible cooling measures and many factors that concerns the implementation is discussed in an article[3] “Solar geoengineering to reduce climate change: a review of governance proposals” written by Jesse L. Reynolds 2019 and published in The Royal Society.

The good news, conveyed through the article, is that it seems possible to cool the planet relatively fast at a very manageable annual cost on an international scale. The bad thing is that there are risk and governance issues involved that makes necessary international agreements difficult to make. Risks that also make IPCC hesitant.

According to Dr Reynolds, research concerned with geoengineering had thus fallen into disrepute until a few years ago after the realization that the possibility of taking away CO2 out of the atmosphere using technology is still far away in time. The realisation that the 1,5 and even 2-degree limit of maximum warming is going to be extremely difficult to meet has woken new interests in methods of cooling the planet apart from only by reducing CO2.

The risks involved with vailing includes acidification through injecting Sulphur in the atmosphere, effects on the levels of Ozon, negative effects on plants and less effect for solar energy. One of the reason vailing has been the most discussed alternative of solar geoengineering has been the estimate of low costs in early calculations. Later revision has shown that the total costs is likely to be much higher than the first estimates.

The risks of changing albedo in clouds at see involves changed water evaporation and less reflection as the albedo enhancement, reflectance of sunlight, only works during the day.

Both these most discussed methods are dependent of new technology being designed and financed through the international community. The latter could well be one important reason for the low interest in solar geoengineering as international funding of climate mitigation historically has been difficult to make. It is also easy to assume that agreement, finance, construction, and implementation would take decades to accomplish.

The hesitation is also caused from the concern that serious suggestions of solar geo-engineering could take the focus off quick reduction of CO2 emissions. But - as governments now do have the focus on CO2 reduction, couldn´t direct cooling also be considered now?

Is there a way out of this deadlock? I think it might be. Private funding from the wealthy could lessen finance disagreements. Solutions implemented on land rather than air and sea could make projects easier to agree upon as only few countries at the time needs to be involved. Not relying on non-existing high-tech solutions could lessen risks and doubts.

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[3] Reynolds J. (2019) *Solar geoengineering to reduce climate change: a review of governance proposals* Accessed September 11, 2021, from https://royalsocietypublishing.org/doi/10.1098/rspa.2019.0255

Decentralization and simplification as a key to acceptance of geoengineering

Can decentralization and simplification help to implement mitigation solutions? Apart from spreading the finance to the many wealthy, could implementation go faster if many individuals around the planet also could participate in the work? And could localizing cooling measures over the planet help in both balancing and adjusting the temperature?

Measures implemented by many regardless of where, also needs to be simple meaning possible to be handled by millions without special, complicated, and expensive technology.

A combination of distributed methods implemented in large scale will be needed

As far as I can see immediate cooling of the planet is needed in parallel, not instead of, the necessary reduction of CO2. Taking the level of CO2 down needs to be organized in parallel, not instead of, taking the increase of CO2 down. Massive electric generation also needs to be implemented and produced fast and close to where it is consumed.

The methods I have suggested below, to be a first choice, are as far as I can judge low-tech meaning easy and fast to set up and not dependent on exclusive skills for installation and maintenance. They are passive, not consuming energy. They are scalable in a sense that installations are economical both for small local units and large. The economic risks are limited to efficiency meaning risk of being more expensive while still working. The environmental risks are limited by reversal being possible. Their contribution towards mitigated temperature increase is measurable. The methods can also be combined with other measures to be more economical.

The methods are suggested and researched by others. My modest contribution is suggestions of applying the methods, fully aware of that there might be other alternative ways of doing this. However, I have suggested concrete examples, as a base for further discussions, with figures sketching the feasibility for necessary levels of measures.

Cooling the planet independently of CO2 reduction could be the best alternative after all

Cooling the planet directly, instead of only by reducing CO2, could be the most effective way to quickly reverse global overheating after all. The obstacles involved vary with the methods and some could be more acceptable than others. The reason I believe in direct cooling is the time it will take to reduce the few thousand gigatons of fossil CO2 already in the air, as the only remedy, before sufficient cooling of the planet will occur. In spite of existing plans by many countries to bring present emissions to zero in about 30 years, some 40 gigatons are still added in the air each year. It is easy to believe that the necessary reductions, to reverse global overheating, will take a few hundred years after the increase have stopped.

There are more serious concerns from politicians all over the planet caused by the knowledge that the present goals of 1,5-2 degrees might not be met. Harsher measures might be needed, and those measures will not be easy to implement. Choosing direct cooling might just offer the planet extra time to recover and the inhabitants less likelihood of having to give up some of the nice habits they have grown accustomed to.

Making CO2 invisible for heat transmission

An idea, not yet discussed so much, as far as I have found, involves the possibility of excess heat on the globes surface being radiated to universe, day, and night, using newly developed materials that emit specific wavelengths of infrared rays *penetrating* the atmospheric CO2. It could be technically and economically possible to use the method to cool the planet according to an article[4] written by Professor Jeremy Munday at Maryland University. He is referring to the article as back-of-an-envelope-calculation and stating that more research is needed resolving risks and further economic and technical issues. The critic I have found concerns the risk of disturbed weather patterns and practical and economic matters with covering large areas with film or paint. Taking professor Munday's reservations into account to me this way of cooling could well be the best of available solutions and my personal view is that it ought to be implemented gradually as soon as possible and researched and optimized as implementation is scaled up. If closely monitored, change in weather patterns could be noticed early and new alternative locations found for further expansion. I believe such risks should be accepted and handled on the way as the alternative is the risk of the sea level rising by up to 3 meters in 80 years´ time or the global warming inducing a tipping point with unknown consequences.

Sufficient radiative material, film, or paint could cost around 2 trillion US $ from present sources according to Professor Mundy. The price would likely come down with higher volumes. On the other hand, costs for necessary infrastructure needs to be added depending on implementation. Radiative cooling is passive – it works without adding energy, so there is no running cost. The method entails the use of a large areas of land, but these could be divided into smaller areas around the globe. Approximately 5 trillion m2 or 5 million km2 would be needed as a minimum. The figure will be higher depending on weather conditions. So far professor Munday's information.

Producing fresh water could be economically feasible with new radiative material

Radiative Cooling produces water through condensation[5]. As the new material also work in daytime, the amount can reach 1 liter/m2/day even in arid areas thus offering an alternative of fresh water supply. In rural areas it could be a supplementary advantage in addition to the cooling effect. 1 liter/m2/day soon adds up, 1 km2 equals 1000 m3.

Increase the reflection of incoming sunlight

As the oceans cover 71 % of the globes surface the cooling potential involving oceans are interesting as it can both off-load cooling measures needed on land and even out the cooling effect between oceans and land.

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[4] Munday J. (2019) *Tackling Climate Change through Radiative Cooling* Accessed February 10, 2021 from https://ece.umd.edu/news/story/mundayrsquos-research-aims-to-mitigate-climate-change-through-radiative-cooling

[5] Cornell University, Zhou (2018) *Accelerated Vapor Condensation with Daytime Radiative Cooling* Accessed February 11, 2021 from https://arxiv.org/abs/1804.10736

The light from the sun absorbs differently due to the albedo that vary from 0, total absorption to 1, no absorption[6]. Open water has 0.1, ice 0.4 and snow 0.9. To stop further ice melting at the poles, increase forming of new ice and contribute to a general cooling of the planet by increasing albedo is therefore a very interesting mitigation option.

In a late study[7] albedo was increased by pouring a thin layer of white very small floating microspheres, or sand-like material, over a limited area thus cooling the area between 1-3 degrees in turn delaying ice melt in the spring and increase the speed of ice forming in the autumn. The material is easy to produce, and resource is unlimited. No negative effects have so far been noticed on the environment or animal life using the material.

In a modeled extended scenario significant results with increased ice-forming could be expected spreading the microspheres over an area between 15.000 and 100.000 km2 where ice naturally form in the arctic. Calculations were based on 25.000 km2. Estimates suggests a need of 300.000 tons to a price of 300 million US $. Transport covering rail and ship is estimated to about 4% on top of the material.

Calculations show that used over a global ice forming area 2% decrease of ice / decade could alter to 6% increase of ice / decade. Over a period of 40 years this sort of global albedo modification could prevent a 1°C rise in average global temperature.

If further research verifies results and proofs that up-scaling is possible this method of increasing the albedo could be very effective. The method also compares favorably economically with daytime radiative cooling.

However, using floating microspheres in the sea have the potential to pollute shores in the same manner as pollen do in the spring. How this compares to seaweed that naturally collects at the shores and how long the microspheres are floating needs to be investigated. One way of dealing with this could, if possible - I am speculating, be to alter the composition of the microspheres so they sink after a certain time. Ideally sinking above a certain temperature, high enough to float in arctic waters but sink in more temperate waters or sink after a certain time. As the material is of a ceramic nature it would eventually form a thin layer of sediment on the ocean floor. Of course, to keep the cooling effect over time the spreading of microspheres would have to be repeated at a certain interval, but as the method is relatively cheap to implement it could still turn out feasible.

Using lakes could be an alternative for the use of microspheres as well as in the seas. Of course, applied in remote unpopulated areas and probably combined with oil booms to keep the microspheres from floating downstream on rivers floating from the lakes.

[6] Wikipedia, (2021) *Albedo* Accessed June 24, 2021 from https://en.wikipedia.org/wiki/Albedo

[7] Bhattacharyya, Mlaker, Sholtz, Decca, Manzara, Johnson, Christodoulou, Walter, Katuri (2018) *Increasing Arctic Sea Ice Albedo Using Localized Reversible Geoengineering* Accessed June 24, 2021 from https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018EF000820

Trees – the most cost-effective way to soak up CO_2

Planting trees is currently the most economical way of reducing CO_2 according to many sources. The cost for one plant can be as low as 0,3 US $ and fully grown it has absorbed between 200 kg and 1 ton of CO_2. Estimates vary. However, it takes 40-100 years to do it. The possibility of planting one trillion trees as a climate mitigation option has been suggested by Professor Tom Crowther[8] a few years ago. His article was both criticized an applauded and resulted in new initiatives but also a discussion of the limits of forrestation. As I understand planting one trillion trees is stretching it, because of the limited amount of available land, so it would be difficult to do that size of planting more than once or perhaps twice. Trillions of trees can be a good help in reducing the level of CO_2 in the air, however.

Forestation can be bought today at a price under 20 US $/ton of CO_2 removal effect. Theoretically the wealthy 1,5 billion people could all buy offsets for 20 US $ each per month and that way nearly half the current emission of CO_2 from 40 gigatons to 22 gigatons a year. There will not be enough land to do this continuously however and the price is bound to go up with higher demand. For investors of offsets, I think forestation still should be prioritized as long as forestation projects are available.

As an alternative of planting new forests on new land, with the main uptake of CO_2 at the end of the tree´s life cycle, new land could instead be used for fast growing fruit baring plants as a source for biofuel. The CO_2 uptake would thus go faster, and the temporary addition of CO_2 would be shorter as the time from harvesting until the crop is turned into fuel, distributed, and finally combusted producing CO_2 could be close to the time new fruits would grow, replacing the fruits that was just consumed. And absorbing the same amount of CO_2 that was released nearly at the same time.

Enhanced weathering could be the CO_2 decreasing method of the future if scaled up

The method entails mining and grinding minerals, olivine, or basalt, and spreading fine particles over land or sea where it soaks up CO_2. It takes time for the dissolvement to take place, however. 25% in 30 years has been stated by Oxfam, se last reference of this page. The minerals are unlimited in supply and dissolved at sea there is a co-benefit of neutralization of the acidification caused by CO_2. Enhanced weathering is also relatively inexpensive – presently from about twice the price of planting trees.

Enhanced weathering is not going to help the acute problem of global overheating but can over a few hundred years, when forestation has been exhausted as a method, be the method that eventually takes most CO_2 out of the air.

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8 Crowther T. (2020) *Backing the trillion-tree campaign to combat climate crisis* Accessed February 11, 2021 from https://www.theguardian.com/science/2020/feb/21/backing-the-trillion-tree-campaign-to-combat-climate-crisis

Distributed electric generation could soon be the most economical alternative

Electric energy needs to come from new sources instead of from oil, gas, and coal. At the same time more electricity will be needed for many climate measures like electric cars, steel production using hydrogen instead of coal and CO_2 capture.

Solar energy in combination with batteries could be the most economical source of continuous electric energy in most places on earth from year 2025 according to an article written by Group Vattenfall[9]. Private solar panels can reach significant effect. With approximately 150 m2 of solar panels a household can be self-sufficient[10] all year around, even in a cold country like Sweden, using electrolyzes, hydrogen storage, fuel cells and accumulators and giving enough power even for charging cars. As a high-end solution it shows what ultimately can be done and done using the roof of a single private house. Smaller private solar installations can partly offload household cost and if installed in large numbers and combined with battery storage offload the public electric grid to a large extent.

Many local and small-scale combined measures done at the same time will be needed

Radiative cooling, solar panels and planting trees can all be installed or planted locally, in small scale, in big numbers, and are easy to maintain. Done by many persons simultaneously significant results could come very fast. The areas of land, walls and roofs needed will then be easier to find and integrate in local environment compared to large-scale implementations.

Land and space will be the limiting factor of radiative cooling.[11] 5.1 million km2, is needed to completely reverse global overheating to zero. It´s a lot of land – that could be found.

What sort of land could be used?

Barren land, typically deserts, salt flats and rocks cover 28 million km2 on the planet. The Sahara Desert alone cover 9 million km2 and the next 10 desserts together the same area again. Grazelands cover 40 million km2. Forests 39 million km2. Land for growing crops 11 million km2. Urban areas 1,5 million km2. Of course, the area needed for radiative cooling and albedo increase must be divided and spread.

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[9] Vattenfall (2018) *Solenergi det billigaste energislaget 2025* Accessed Mars 13 2021 from https://group.vattenfall.com/se/nyheter-och-press/nyheter/2015/solenergi-det-billigaste-energislaget-2025 Solarenergy the cheapest source of energy 2025. Google translate gives good enough english

[10] Nilssonenergy (2021) *Self-sufficient houses by solar-panels and hydrogen storage* Accessed February 11, 2021 from https://nilssonenergy.com/?fbclid=IwAR1LoeC4zOiO1QQQ8NB-k9ddWRxcNACSNzkUMPtvMn2DLxbP2v_NCkBwBHs

[11] Our World in Data (2019) *Land Use,* Accessed Mars 2021 from https://ourworldindata.org/land-use

Spreading the task on different countries, communes, and different sorts of land

It must be proven of course, but my belief tells me that spreading cooling measures as much as possible around the globe would lessen the risks and negative effects because of disturbances in weather patterns. To understand what could be done one need to see the proportions of needed land use. I have made an example based on conditions in Sweden where I live.

The area of the earth is 510 million km2 and the area of the land is 149 million km2. The area of Sweden is 0,45 million km2 or 1/331 of the earths land surface. If Sweden were to house a proportional part or 1/331 of the global needed area of 5 million km2 Sweden's area would come to 15106 km2

There are 290 communes in Sweden so the share per commune would come to an average of 52 km2. Applied on Lidingö commune, a suburb of Stockholm, where I live it would be an exact fit! Lidingö:s area is 51 km2 for a population of 42.000. The situation in the town of Kiruna in the north of Sweden is a little brighter with an area of 20551 km2 for a population of 22.000. 403 times the size of Lidingö with half the population.

The very top of Sweden is used as a crashing site for rockets launched from ESA the European Space Agency. That area alone is about 5600 km2 or more than a third of the total space needed for Sweden. The area type is tundra, unpopulated, without roads and speckled with small pond-size lakes and bare rocky areas.

The land-use would of course be different in rural- and urban- areas and on different places on the earth. Northern countries could use forests and lakes as part of the needed areas. Many countries could use parts of fields. Hot countries could use deserts. Populated areas would need to use the space in scarcely populated areas.

Scarcely populated areas with temperate climates with a lot of small lakes, like the northern parts of Canada[12], Norway, Sweden[13], Finland, and Russia, could have radiating film or albedo increasing microspheres floating on remote lakes. Choosing lakes in remote areas should of course be prioritized in order save environmental values. There are a lot of lakes and the very north is speckled with very small lakes or "ponds". 10 % of the Finnish land-area is covered by lakes, 9% in Sweden and Canada. Russia and Canada have about 2 million lakes each. Sweden and Finland some 100.000 each. Choosing lakes, the albedo would also increase from nearly total light absorption from open water to nearly total reflection from ice and snow when the winter season is prolonged. Cooling in the northern parts of the planet would also be extra beneficial as those areas are sensitive due to thawing permafrost.

Roofs on buildings can be used. The new radiating materials cool even in sunlight. If installed where air condition is needed, cooling material can save electricity consumption. In lesser developed areas panels could be utilized directly on top of roofs and cool houses without air condition. The panels could if they were used for cooling houses be seen as an investment at no cost but instead possible profit. In urban areas parking spaces, roofs on shopping areas,

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[12] Wikipedia (2020) *List of lakes of Canada*, Accessed August 4 2021 from https://en.wikipedia.org/wiki/List_of_lakes_of_Canada

[13] Wikipedia (2020) *List of lakes of Swede*n, Accessed August 4 2021 from https://en.wikipedia.org/wiki/List_of_lakes_of_Sweden

median strip on motorways, track areas at railway stations could be used. Walls on buildings could be used with panels aiming at the sky at an angel.

Cost-effective ways of covering surfaces with radiative material

Spraying paint could be a way of covering large areas where it could be environmentally permissible. Spraying very fine mist of paint so the receiving areas would only partly be painted could be an alternative if the proportion of paint is small. The appearance could then be seen as a slight matting of the receiving surface. Depending on application the concentration of paint could vary. In the following examples, I have suggested a concentration, or opacity, of 10 %. Of course, the cooling effect would be reduced in the same proportion.

The fastest way of covering large spaces would be by air. A combination of land-based transport and air distribution could then be needed. A flexible way could be using drones supported by small trucks for paint, battery support and personnel. The advantage would be independence from airfields, the possibility for large scale use of parallel distributed workforces and much better control of the sprayed areas compared with from airplanes.

Drones used for agricultural purposes can typically cover 100 acres a day[14] at a 3 gallon per acre application rate. Translated to approximately 40 ha a day at a 4,5 liter per ha application rate. As the application rate is based on pesticides the necessary volume / day needs to be adjusted for the use of paint instead of pesticides.

Assuming a 10% coverage of paint, meaning 10 % paint and 90% no paint on a surface, equals a layer to a thickness of 2 µm. In tables[15] showing theoretical spreading rate, m2/l, at different % solids (the paint itself) and solvents, 20 µm is the thinnest layer and at 50 % solids that layer would cover 25m2/liter. According to the assumption 2 µm would then give 250m2 per liter or 40 liter per ha at 10% coverage thus reducing the application rate by a factor 9 compared to the application rate of pesticides. That would give an application rate of 4,5 ha/ day or 22 days per km2 for 10% coverage.

The numbers of necessary drones and the cost involved to do the job could be feasible according to conditions described in the next article. Presently around 1 million commercial drones a year[16] are manufactured and as the need could be significantly smaller than that number the acquisition of drones should not be a problem seen over a few years.

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[14] Rantizo (2021) *Rantizo FAQ* Accessed August 2021, from https://www.rantizo.com/faq/

[15] Dulux protecting coating (2014) *Handy Calculations – Volume solids spreading rates* Accessed August 2021, from https://www.duluxprotectivecoatings.com.au/media/1581/531_handy_calculations-vol_solids_spread-rate.pdf

[16] Drone Industry Insights, Schroth (2020) *The Drone Market Size 2020-2025 5 Key Takeaways* Accessed August 2021, from https://droneii.com/the-drone-market-size-2020-2025-5-key-takeaways

Agricultural drone services, including drones, pilots and support services can be bought today for about 1300 US $/8 hour-day[17].

Apart from paint the cooling material could also be applied as film.

Radiative film or sheets could be applied on top of some surfaces without any extra support. Roofs and in some circumstances, ground could be examples of suitable surfaces.

Film could also be applied in more complex structures where other benefits apart from cooling could be utilized. The investment in film-support could then be shared.

Barren lands could be used to a large extent

Of the 28 million km2 barren lands on the planet large parts are covered by deserts. Deserts are also mostly covered by rocks and stones. Only 10-20 % of the 9 million km2 in the Sahara Desert is covered by sand. If 80% of all barren land is not covered by sand, and without a big likelihood of being covered by flying sand, the area amounts to 22 million km2. As the need of space for reversing overheating is 5 million km2, deserts are a natural first to consider.

The simplest way of covering rock with radiating material in the desert would probably be painting it. Of course, it would affect the environment, but paint will wear of in time and the environment is likely to be restored by wear when the need for cooling the planet is gone. Surfaces could be partially covered by reducing opacity making them more transparent or by covering selected areas or probably a combination of both. Let's assume 10% could be covered. That would amount to 2,2 million km2 or nearly half the need of 5 million km2.

Forests are some of the largest global areas and could perhaps be partly used

Contents of forested areas are complex with more than living trees. Some areas might be permissible for low opacity paint cover or albedo-increasing microspheres. Areas of dead trees, newly felled areas, areas struck by wildfires, and rocky areas to name a few. The diversity of forested land appears clearly on arial photos.

Sweden's land area is covered by forest to 69% or 230.000 km2. 10% areal cover would give 23000 km2 and with an opacity of 10% of active radiating area would give 2300 km2. If the need to cover Sweden´s quota would be 15.000 km2, painting forests could cater for 15% of the need. 7% if the cloud-cover of the sky is present 50% of the time. Of course, the painting would have to be done in new places as the used areas get covered again with trees and plants. 7% of Sweden is covered by boglands where microspheres could be used for cooling.

If forests would be accepted and effective for cooling use, big climate gains could also come from Russia with 8 million km2 of forest, Brazil with 5 million km2 and the US and Canada with 3 million km2 each as well as many other countries with forests.

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[17] Droneblog, Ciobanu (2021) *What to Charge for Drone Services* Accessed August 2021, from https://www.droneblog.com/what-to-charge-for-drone-services/

Using surplus farmland could be the fastest and most economical way to find space

With higher yields from growing crops approximately 7 million km2 of the 11 million km2 used for growing crops on the planet is not needed anymore and could partly be used for other purposes. Rolling out radiating film on these surfaces longer periods of time could be a fast and convenient way of covering large areas. Technologies exist that can roll out film on a commercial scale using non-complicated attachments to an ordinary tractor. Equipment used for soil solarization[18] could probably be used for this alternative purpose.

Apart from radiating heat such film would also preserve water content in the soil by stopping evaporating. The method would instead add water to the soil by condensation.

Combining cooling and water condensation as well as combining land use

The total cost of implementing radiating film and installation for water production could be lower if the cooling and water production capabilities could share needed investments. The examples below give a hint of what could be investigated further combining cooling and water production in deserts and grazelands.

Water production as the facilitator for cooling installations in different applications

Presently there are 16.000 desalination plants[19] in 177 countries in the world producing 95 million m3 of water a day. The biggest desalination plant in USA, The Carlsbad[20] plant in San Diego, produces approximately 190 million l of fresh water/day. The investment cost was 1 billion US $. To produce the same amount of water through radiative cooling condensation 190 million m2 or an area of 14*14 km would be needed for radiation surface, and the material could cost 76 million US $. Of course, a lot of roads and technical structures would have to be added to the cost to be comparable with the investment of the Carlsbad plant. With the forecasted future lack of freshwater, the build of many more desalination units can be anticipated. As desalination is controversial as being expensive to run and brine-polluting, alternatives should be welcomed.

Combinates could be set up in desert areas with the water production through radiative material as facilitator. Plantation of oil palms, for fuel production, doesn´t have to be controversial on new, not previously used land. With a water consumption of 350 l/day some 400m2 or 20m*20m would have to be allocated for each palm. The large radiative area per tree would also compensate for the lower albedo of trees compared to sand and thereby ensuring a net cooling effect. Large amounts of water would condensate out of air but as

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[18] Masabni, Franco (2013) *Soil Solarization* Accessed June 2021, from https://agrilifeextension.tamu.edu/library/gardening/soil-solarization/

[19] Researchgate (2019) *Number Capacity and Global Share of Operational Desalination Plants by Region Country* Accessed February 14, 2021 from https://www.researchgate.net/figure/Number-capacity-and-global-share-of-operational-desalination-plants-by-region-country_tbl1_329476006

[20] Wikepedia (2020) *Claud "Bud" Lewis Carlsbad Desalination Plant* Accessed February 14, 2021 From https://en.wikipedia.org/wiki/Claude_%22Bud%22_Lewis_Carlsbad_Desalination_Plant

trees transpire when they grow some 90% of the water would return to the air. The plantation could in turn produce biochar by solar powered pyrolysis from residues from the fruits used for oil production. As the carbon in biochar stays stable over time that would in turn contribute to lower the level of CO_2 in the atmosphere. That type of combinate could directly cool the planet, facilitate production of fossil free fuel, and reduce CO_2 in ambient air as the fruit residues were pyrolyzed into biochar. And the biochar could in turn fertilize the oil plants to produce higher yields and keep water in the soil.

Assume a part of the 40 million km2 of grazeland could be used for parallel purposes without disturbing the use for feeding cattle. With some planning, land could thus be shared between grazing and radiative cooling. Radiative cooling on grazeland could also produce water from condensation. This way the same land could be used for three purposes without any loss to any of them. The produced water could be used directly to feed the cattle or organized in large scale forming water production facilities for distant use.

Research on changed weather patterns parallel with gradual implementations

Of course, local cooling and condensation of the magnitude described in the examples earlier in this article would change weather patterns. The more spread the cooling measures are, however, the less change of weather would likely occur – this is my assumption. As weather patterns already are changed needed measures could alter the effects seen today with fires and both increased droughts in some places and more rain in others. More research is needed of course but could be done in parallel to installations. Ideally the location of new cooling installations could be placed to even out present disturbances.

No problem finding enough projects for climate measures

The methods described so far, except of desalination, have the advantage of being low-tech. They can all be installed, applied, or planted fast, by many, locally and to a low cost per unit. And there would be no problem finding enough measures that could contribute to reverse global overheating even if billions of people would participate with 20 US $/month.

Other methods of CO_2 removal are dependent on factories being built, mines opened, transport and high energy consumption. Some of these methods, I believe, are presently too expensive to be realistic options but could be good alternatives later, when cost has come down and more non fossil based energy has been made available. Oxfam has published a comprehensive compilation[21] of different measures for reduction of CO_2 and what they cost.

As described in this article, there could well exist feasible methods and technologies that could totally reverse global overheating relatively fast, take away a good chunk of CO_2 in the air and substantially increase the generation of electric power in a sustainable way.

To get such mitigation processes going fast and simultaneous on a global scale new organizational and financial mechanisms need to be put in place. However, I don´t think knowing what to do is enough to get things going. Better ways of motivation are needed.

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[21] Oxfam (2020) *Removing Carbon Now* Accessed February 11, from https://oxfamilibrary.openrepository.com/bitstream/handle/10546/621034/bp-carbon-removal-now-190820-en.pdf?sequence=4&isAllowed=y

In the next few articles, I will suggest some organizational and motivating ideas that I believe could get climate mitigations, as described in this article, started fast globally.

Please share this article if you sympathize with the thoughts. Also see www.climesave.com