amr ag
atmospheric methane removal ag
https://amr.earth

Kreuzlingen, Switzerland, 27.08.2024

The Solution to the Climate Crisis

The following presents a concept that solves the climate crisis. This statement is provocative, but nonetheless means exactly what it says. The climate crisis can be solved.

The Climate Crisis

The climate crisis is a scientific and political phenomenon of modern times. In the 21st century it became known to a large audience. The climate crisis is synonymous with global warming caused by greenhouse gases, in particular carbon dioxide, methane and others. These greenhouse gases are predominantly produced by humans and released into the atmosphere.

The Established Solution

Mainstream science and politics propose the climate crisis to be addressed by reducing or eliminating the sources of global warming, i.e. the burning of fossil fuels or emissions from livestock.

The Flaws in the Established Solution

The established solution is not wrong, but insufficient. The problem cannot be solved with emission reductions alone. Even after a complete stop to the burning of fossil fuels, the climate crisis would persist. This is the case mainly because global warming is caused by greenhouse gases already up in the air which remain unperturbed by future reductions.

In case of methane - emission reductions would in fact work, because methane has an average atmospheric lifetime of 10 years and would therefore gradually dissipate if emissions were cut. However the proliferation of millions of methane sources, both anthropogenic and natural, makes methane emission reductions extremely expensive.

The Solution to the Climate Crisis

In order to solve the problem of the climate crisis, it is crucial to remove the existing greenhouse gases from the atmosphere - in addition to the established solution. This second measure is just as important and even more urgent for the next 50 years. Since the removal affects gases already present in the atmosphere, it does not compete with the established solution, which is targeting future emissions. Henceforth there exists no “Moral Hazard”, a concern often raised, as it complements rather than undermines the established solution.

Two Greenhouse Gases

Global warming is mainly caused by the greenhouse gases carbon dioxide (CO_2) and methane (CH_4), compare Fig. 1. Although other greenhouse gases exist this article focuses on these two major contributors.

The most potent greenhouse gas is CO_2, it is responsible for approximately 0.8 °C of the current 1.2 °C rise in global temperatures. The technical removal of CO_2 from the atmosphere by Direct Air Capture (DAC) is laborious. There is a growing industry dedicated to it but even the greatest optimists admit that the process is unlikely to become economically viable for large-scale climate cooling. However there is hope, not so much for technical removal, but for natural CO_2 reduction. Plants bind most CO_2 through photosynthesis, at least temporarily, and there is no objection against more plants on earth. Admittedly the once favoured land-based projects e. g.

growing forests have largely failed to deliver the promised CO_2 reductions, due to their proneness to destruction by wildfires. Having learnt that lesson the most promising strategies target the largest CO_2 sink on earth, the oceans.

The second most important greenhouse gas is CH_4 (methane), which is responsible for around 0.5 °C of today's global warming. The methane content of the atmosphere is rising sharply, outpacing CO_2. While reducing anthropogenic emissions (compare https://www.globalmethanepledge.org) is preferable over removal, it is unlikely to significantly lower atmospheric methane - due to the multitude of emission sources. The good news is: CH_4 oxidizes in the atmosphere to CO_2 and water (H_2O). Since CH_4 warms the climate about 120 times as much as CO_2, this oxidation instantaneously reduces global warming. Accelerating this natural process could bring methane levels back to pre-industrial levels, potentially cooling the climate by 0.5–1.0°C. The actual potential depends on the abundance of methane in the atmosphere, which is rising.

Climate-cooling Gases

Also relevant to the debate are two other anthropogenic gases that have a major impact on the climate but, unlike greenhouse gases, have a climate-cooling effect. These two gases are sulphur dioxide (SO_2) and nitrogen oxides (NO_x). Until recently, SO_2 alone has contributed to a 0.5°C cooling effect—equal to the warming effect of CH4—while NOx accounts for approximately 0.2°C.

SO_2 and NO_x are well known as causes of acid rain and respiratory infections. Due to these harmful properties emissions of these gases, especially SO_2, have been continuously reduced in recent decades. This reduction is good for the forest and our lungs, but it further exacerbates the climate crisis, as the climate-cooling effect is lost. We can see here that the climate crisis is not just another 20th-century-style environmental crisis. On the contrary, the "old" polluters can even be found on the "good" cooling side of the equation. The climate crisis can be therefore be referred to as "Pollution 2.0", analogous to "Web 2.0". We could cool the global climate down at any time by switching off the filter systems in coal-fired power plants and diesel-powered ships that we have just installed for a lot of money. Nobody will seriously demand that - but understanding it is relevant. It shows that humans not only warm the climate but can also cool it and have already done so. Global temperatures are under human control.

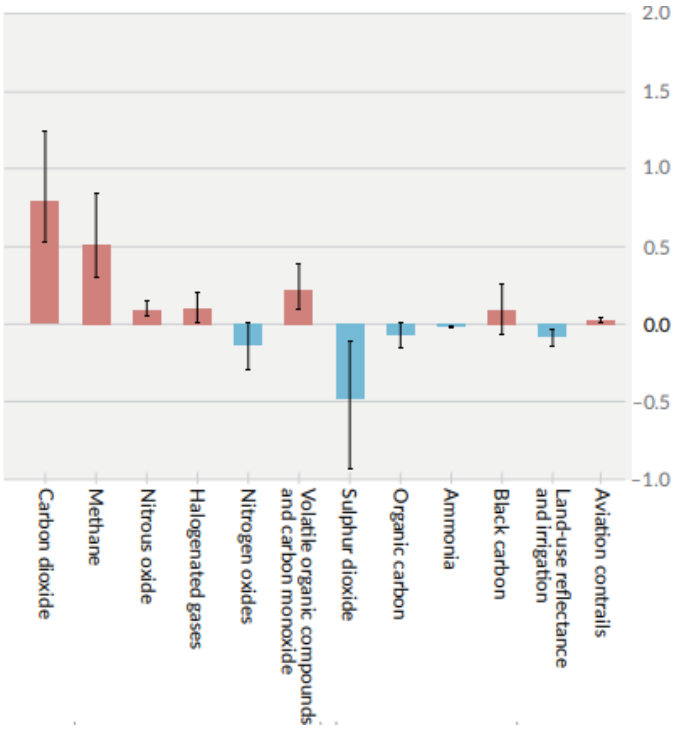

Figure 1. Gases/particles in the atmosphere and their impact on global temperature in °C.

Compare Page 7 of IPCC, 2021: Summary for Policymakers

Removing CH_4 and CO_2

CH_4 and CO_2 account for approximately 90% of global warming. AMR AG is developing technology specifically designed to remove CH_4 from the atmosphere, with CO_2 reductions as a welcome bycatch.

The plan is to add ferric chloride ($FeCl_3$) to the atmosphere over the next 20-100 years. The material will be dispersed from aircraft at an altitude of around 2,000 meters above the Pacific and Atlantic Oceans. $FeCl_3$ is commonly used for wastewater treatment, it would now serve a second role in purifying the air.

$FeCl_3$ contributes to the oxidation of CH_4 under UV light (sunlight), it accelerates the natural process of methane oxidation. $FeCl_3$ has had this atmospheric effect for millions of years, the process is entirely natural. The oxidation, accelerated by the dispersion of additional $FeCl_3$, is called "Enhanced Atmospheric Methane Oxidation" (EAMO) (see https://en.wikipedia.org/wiki/atmospheric_methane_removal).

$FeCl_3$ dissolves to form salts and iron, depositing iron in the ocean or on land, which acts as a fertilizer. This promotes the growth of additional algae in the ocean, see https://en.wikipedia.org/wiki/iron_fertilization. When algae die, some sink to the ocean floor, sequestering CO_2 for thousands of years. This way "Ocean Iron Fertilization" (OIF) removes CO_2 from the atmosphere.

OIF is probably the key to CO_2 drawdown. It can be done not only in conjunction with EAMO but also on its own. The oceans have huge capacities and can easily store all atmospheric CO_2. What EAMO is for methane, OIF is for carbon-dioxide.

Aligning with the Forces of Nature

Both EAMO and OIF are methods which depend largely on natural processes. Global warming unleashes natural forces which relocate billions of tons of air, water and matter. It turns nature, which all life depends on, into an adverse force. Human engineering cannot fight nor copy the forces of nature, we are way too small, but we can influence nature's power to reach benign effects. Solving the climate crisis requires thorough understanding of, tight coupling with and deep respect for nature. We can solve the climate crisis if, and only if, we make nature our ally. Humans are only one small element in the great universe and should accept their role with modesty. Doing so will reopen a long-term perspective for all creatures on our planet.

The Role of AMR

AMR has been researching EAMO since 2021, establishing its own laboratory to simulate, measure and detail the process. The results are promising, but some questions about atmospheric effects remain. Only field trials can provide definitive answers.

Additionally AMR develops technology for the dispersion of $FeCl_3$ nanoparticles from planes or drones.

Methane Emission Reductions

Whilst methane emission reductions could reduce the scale of the problem, they will not suffice. Due to the magnitude of the task a combination of emission reductions and atmospheric removal is necessary, with emission reductions being the preferable approach.

The Cost of Methane Removal

According to initial estimates methane removal and emission reductions will cool the climate by 0.5 to 1.0 °C within 20 years, at a yearly global cost of 1 – 3 billion $. This is equivalent to a cost per tonne of CO_{2e} of around 0.5 – 1.60 $.

Managing the Climate

If humans learn to cool the climate, a lot will have been gained. But the ability alone will not suffice, humanity must also decide to actually do it. This requires considerations far beyond natural science. Moral criteria are to be applied to evaluate interventions in the atmosphere. Ecological and social effects need to be researched. Risk

assessments are required to weigh the risk of all measures against that of further unchecked warming and deterioration. Many scientists from a wide range of disciplines are needed, from countries all over the world. AMR cooperates with various universities worldwide. This work will still take some time - on the other hand, time is pressing, global warming already claims lives every year and causes huge losses of assets. It is advisable to start building the infrastructure and research the effects during the upscale.

In order to bring all the different aspects together, there is no alternative for humanity to : Managing the climate in cooperation with nature.

As a guideline for such global climate management the primary goal should be restoration of the pre-industrial climate. Other possible development paths are fraught with unforeseeable risks and should be avoided.

Summary

The climate crisis can be solved. In addition to the established solution in the form of reducing emissions and abandoning fossil fuels, a second measure is required: Removing greenhouse gases from the atmosphere. This second measure should be implemented as a priority over the next few decades. Two key technologies are available, Enhanced Atmospheric Methane Oxidation (EAMO) for methane and Ocean Iron Fertilization (OIF) for carbon-dioxide. AMR has developed the technology for EAMO and is ready for field testing.

In order to achieve global consensus on the measures to be taken global climate management is required with the goal of restoring the pre-industrial climate in a nature-friendly, sustainable way.