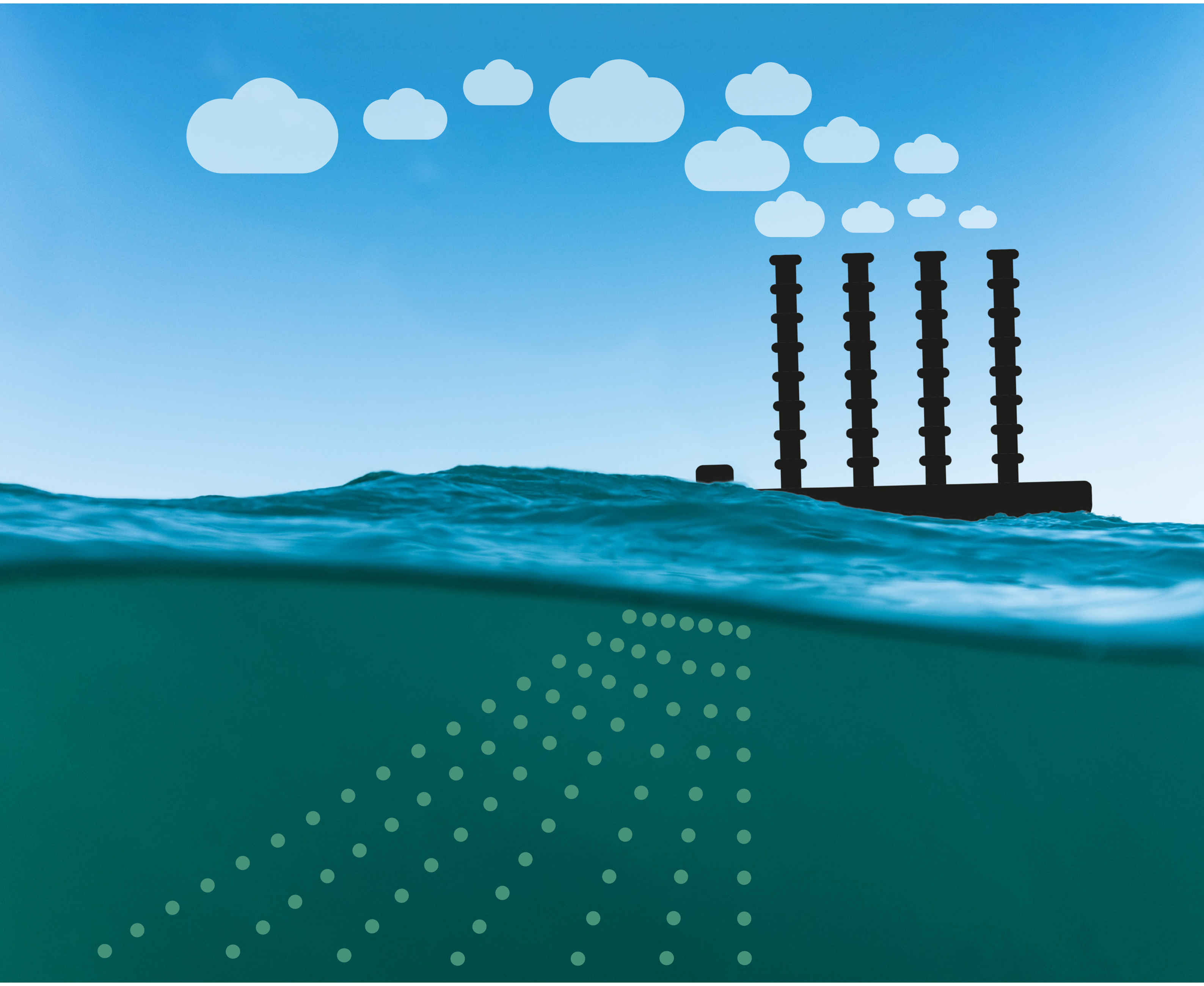
Analysing marine geoengineering technologies



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Contents

"Those players who stand to gain most from the approval of large, new and risky projects are rarely those who stand to lose if the costs of those projects turn out to be far higher than forecast, or the benefits far lower. This creates a powerful incentive for advocates of new projects to underplay the risks and costs."

UK Royal Society 2009: Geoengineering the climate: science, governance and uncertainty.

Most geoengineering schemes will affect the oceans, but this paper is restricted to four technologies.

Two methods are albedo-increasing:

1. Solar radiation management by seeding marine clouds with condensation nuclei in order to make them more reflective, i.e. whiter.
2. Micro bubbles/seafoam that make parts of the sea more reflective, or whiter.

Two methods aim to change ocean biogeochemistry, so as to increase photosynthesis:

3. Using the oceans as carbon sinks through trace element fertilisation, especially iron. The idea is to produce "algal blooms" to increase photosynthesis, after which the photosynthesising organisms sink to the ocean floor and store the carbon there.
4. Ocean upwelling of nutrient-rich water.

None of the methods are new, none is tested on any meaningful scale, and they all have a certain "Mad Scientist" tinge. The ideas in themselves may not deserve much respect or attention, but they keep reappearing, in the general news media (where they are usually presented as brand new solutions for the climate) and also in scientific publications.

This warrants a statement of position from NGOs on marine geoengineering, even though the NGO community itself has a solid consensus on what will actually save the planet from overheating. (See Appendix.)

1. Marine cloud brightening

Physical mechanism: Tiny salt particles create more condensation nuclei in clouds, so that a larger number of smaller droplets are formed. Clouds, usually mid-height alto-cumulus clouds, made up of smaller water droplets then become more reflective, i.e. brighter from above.

Technology: Finely ground sea salt is sprayed up from tall chimneys on ships, manned or unmanned. The most common proposal for achieving such a goal is to inject naturally occurring sea salt into cloud updraughts[1].

History of idea: One of the leading proponents of marine cloud brightening, John Latham, proposed the idea in Nature[2] in 1990. Several respected and influential scientists are among the proponents. Promoted by Bill Gates[3].

1 https://keith.seas.harvard.edu/marine-cloud-brightening

2 https://www.nature.com/articles/347339b0

3 https://keith.seas.harvard.edu/FICER

Costs are largely unknown but do not seem prohibitive. A US Academies study estimated the cost to offset all greenhouse warming (5 W/m^2) at 5 billion USD/year[4].

No outdoor experiments so far[5].

Benefits, according to proponents: Could be used for local cooling, for example of coral reefs to counter coral bleaching, or to save icesheets in the Arctic or Antarctic.

Issues: used on a large scale it may influence the whole climate and weather systems, especially rainfall, as well as international relations. If large-scale deployment were to take place, it would have to continue indefinitely or risk a termination shock.

Obviously, salt water particles over the sea constitute no chemical hazard. This might justify experiments for scientific reasons, which could pave the way for larger-scale tests. If such scientific experiments should be performed at all, they should not be left to scientists who have a vested interest[6] in advancing marine cloud brightening.

2. Microbubbles/sea foam

The water in the wake of ships is brighter because of small bubbles. The proposed scheme is to reinforce this effect by adding surfactants such as those used to remediate oil spills and, in lower concentrations, as a widespread pollutant in run-offs from the use of detergents, soap and toothpaste etc.

The bubbles would reflect more solar energy back into space, and thus have a cooling effect. They would also shade the water below, at the expense of photosynthesis there.

The biological effects depend on the type of surfactant, the species, the developmental stage and obviously the concentration. As an example, embryos may be more sensitive to some surfactants than adult fish, according to one study[7].

While it may be possible to pinpoint some surfactants as harmful, and thus exclude them, it seems very difficult to prove conclusively that a certain substance is so harmless that it can be used on a very large scale.

Research, at least up to 2018, has been limited to lab experiments and modelling[8]. But some of its proponents, such as geophysicist and international relations expert Russell Seitz at Harvard, may wield some influence, mainly but not only within the right-wing climate-sceptic community.

4 https://www.nap.edu/catalog/18988/climate-intervention-reflecting-sunlight-to-cool-earth p 125

5 http://www.geoengineeringmonitor.org/2018/05/marine_cloud_brightening/

6 https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017EF000601

7 Wang, Y., Zhang, Y., Li, X. *et al.* Exploring the Effects of Different Types of Surfactants on Zebrafish Embryos and Larvae https://www.nature.com/articles/srep10107

8 http://www.geoengineeringmonitor.org/2018/06/microbubbles-sea-foam/

3. Ocean fertilisation

Some parts of the oceans have low levels of micronutrients, one of which is iron. If relatively small

amounts of iron are added there, it will cause an algal bloom. If a substantial part of the algae (or plankton that eat the algae) sink to the sea floor, this will draw carbon from the air and more or less permanently store it on the sea floor. This idea can be traced back to at least 1989, and although it has not had much traction, it has reappeared several times.

Issues:

- Algal blooms will make the water turbid, and reduce light deeper down, so plants cannot grow and animals cannot see.
- Algal blooms are sometimes toxic and will kill animals.
- The fate of the sequestered carbon is elusive, and the eventual uptake hard to gauge. Ocean fertilisation may not result in any net uptake at all globally.
- Fertilisation is likely to reduce biodiversity; some species will increase their numbers at the expense of others.

4. Upwelling

Cold, deep water that is rich in nutrients can be forced up to the warmer surface by pumping or natural wind. As in ocean fertilisation (above), this would enhance algal growth and suck up CO_2.

It was first proposed by James Lovelock (of the Gaia hypothesis) in 2007.

Unlike ocean fertilisation, upwelling has massive engineering and economic challenges. It requires very large structures. According to one study[9], 7 million pipes, each 1 metre in diameter and up to 1000 metres long would be needed to achieve an upwelling of 1 million m^3/s.

It takes a lot of energy to power such currents.

Geoengineering Monitor sums it up: "Electrical pumps have turned out to be too expensive, and upwelling processes based on differences in temperature or salinity have been too inefficient"[10].

Wave power and offshore wind power have been suggested as an energy source, but wave power is still not a proven technology, and offshore wind is not necessarily cheap or even viable in the deep sea.

Just as with ocean fertilisation, the fate of the photosynthetically sequestered carbon is difficult to foresee. The ecological effects include evidence of growth of potentially toxic algae (cyanobacteria), even after the experiment ended.

9 https://oceanrep.geomar.de/3029/1/1019_Oschlies_2010_ClimateEngineeringByArtificialOcean_Artzeit_pubid13251.pdf

10 http://www.geoengineeringmonitor.org/2019/10/artificial-upwelling-current-efforts-and-anticipated-impacts-of-intermingling-the-ocean/

Experiments have taken place in several locations on a smaller scale, in China, Norway and Australia/Philippines. Results are either disappointing, inconclusive or not yet published[11].

One reason for such experiments is the hope that upwelling will benefit fishing or aquaculture, lending green credentials to it.

Summary analysis:

1. All geoengineering carries a moral hazard. As long as a plan B is presented, focus and urgency to cut emissions is distracted. High-emission industries and some governments in their service have a strong interest in delaying the necessary transition to zero emissions for the short-sighted goal of a few more years of profit. This delay can be achieved even with technologies and policies that are almost certain not to work.

2. All geoengineering schemes will achieve less than actual emission reductions. Emission reductions, where coal power is substituted for wind, solar, efficiency and afforestation, or diesel/gasoline for electricity, or natural gas and coal heat for electricity, have several co-benefits:
   - reduced direct and indirect emissions of N_2O and methane
   - reduced ocean acidification (from CO_2)
   - reduced terrestrial acidification (from NOx and SO_2)
   - health benefits due to cleaner air, less nitrogen eutrophication
   - reduced tropospheric ozone, which is harmful for human health, vegetation and the climate

Afforestation is also a key ingredient (among many) for fixing the biodiversity crisis. Solar radiation management techniques have no such co-benefits. Ocean chemistry modification have much more limited co-benefits.

3. Geoengineering aimed at fixing the long-term climate globally also affects the weather, both short-term and locally. This is divisive, as one nation's "better weather" is another nation's "weather deterioration", affecting harvests, fishing, tourism and forestry. Even the suspicion that weather is manipulated at somebody's expense will create international tensions, which make it harder to agree on how to save the climate.

4. The calls for "more research" on geoengineering should generally be rejected. More research is very unlikely to yield substantial climate solutions on which there is general agreement. It is much more likely to shift focus and resources away from the necessary efforts to cut emissions.

5. "Dual-use" experiments that can improve climate science, or other science, but could also be of use for geoengineering development should be kept under government control, and only be allowed if the scientific justification is adequate, i.e. within the normal procedures of public research funding. It should not be left to attention-seeking billionaires to decide which experiments are to be performed.

11 http://www.geoengineeringmonitor.org/2019/10/artificial-upwelling-current-efforts-and-anticipated-impacts-of-intermingling-the-ocean/

Appendix: Better solutions exist

The case for geoengineering rests on the assumption that the climate crisis calls for desperate action. This is not warranted. The problem is not that we have run out of options. The problem is that we know what to do but are not doing it fast enough.

Many geoengineering ideas became topical back in 2009, when the Royal Society published a review. The idea then was that geoengineering would be easier and cheaper than emission cuts, or that deeper cuts would be politically impossible. Such reasoning was being questioned even at the time. The strongest evidence for the viability of GHG cuts is however more recent.

It is a different world now compared to 2007. It is not only conceivable that substantial GHG reductions can take place. There is data to support it.

Table 1. CO_2 emission, Mtons

	2007	2019	change %
United States	5884	4965	-16
European Union	4226	3330	-21

bp Statistical Review of World Energy June 2020

This was achieved during a period of economic growth, and without anyone trying very hard. 2020 saw a strong global downturn for fossil fuels and CO_2 emissions, while solar and wind was much less affected. Climate policy ambitions are being raised in many countries, especially in the EU.

Also noteworthy is that China, after a long period of dramatically growing CO_2 emissions, more or less stabilised its emissions in 2013–2019, with a growth of just 1 per cent over the six years.

This was not a question of low-hanging fruit, but of general, affordable methods with strong remaining potential. For example solar and wind are rolling out very fast, in richer and poorer countries:

Table 2. Wind + solar PV power generation, TWh

	2007	2019
United States	36	411
European Union	109	569
China	5	630
India	12	109
World	179	2154

bp Statistical Review of World Energy June 2020

One TWh of coal power emits roughly 1 Mton of CO_2 per year; gas power half as much. Renewable energy cuts billions of tons of CO_2 emissions. It can cut much more and is likely to do so with present policies, and still much more with Paris-compatible climate targets in mind.

Initially, wind and solar just added to electricity consumption without subtracting anything, especially in the developing world. In recent years, renewables have reduced the consumption of fossil fuels. CO_2 emissions decreased 12 percent in the OECD and 21 percent in the EU between 2007 and 2019. More to the point, global emissions from power generation fell 1.5 per cent in 2019, much of which can be explained by growing renewables.

This is just the beginning. Data for the year 2020 are not yet available yet, but many analysts believe that peak CO_2 took place in 2019, as coal and oil were severely and permanently hit by the Corona pandemic. Solar and wind kept growing in market shares, though they did not grow as fast in absolute term as earlier predicted.

The corona crisis also saw a dramatic increase in interest in green (electrolytic) hydrogen and batteries. This means that there is almost no limit for solar and wind penetration in the electric power system. The scope is rapidly advancing into other fields such as transport, heating and steel-making.

Opinions are divided regarding the viability and scope of BECCS, but there is unanimity that some of the already emitted CO_2 can be sucked back into the ground by afforestation and altered practices in forestry and agriculture.

Energy efficiency can contribute very substantially to emission reductions. Two examples: LED lighting is expected save 347 TWh in the United States12 by 2027. Heat pumps produced 128 TWh of heat in the EU in 2018 avoiding 33 Mtons12 of CO_2. There are many other efficiency options, many of which are universal. Well insulated buildings save energy the same way whether it is too hot or too cold outside.

Many geoengineering advocates are also pro-nuclear, but unlike solar, wind and efficiency, nuclear power has made no headway. The peak year so far was 2006, and nuclear's share of world electricity is clearly decreasing. Whatever the reasons (cost, long lead times, popular resistance), nuclear is no credible contender to cut emissions fast, for example in the 2030 horizon.

Solar, wind, efficiency and afforestation are much less contentious than nuclear and geoengineering. They are the surer, faster, safer and usually cheaper ways to save the climate.