Proposals for a consortium to implement Climate Restoration

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1 Executive Summary

Climate change presents an existential and growing threat to civilisation and life on the planet. This risk increases by the day. Despite the clear scientific evidence of the worsening situation and twenty one years of negotiation effort, there have been no global agreements to make the cuts in CO2 emissions that are needed.

This appalling situation leaves humanity with no option but to start a programme of climate intervention with the aim of cooling the planet and sequestrating CO2 from the atmosphere. There will be a lead time necessary to develop the technologies and to put in place the manufacturing and logistics facilities as necessary. It is thus essential to start these activities immediately.

This document sets out three technological solutions which in combination can either slow climate change or reverse it. These technologies provide solar radiation management, improved CO2 sequestration by the oceans and re-establish the Arctic ice cap. This document is intended for circulation amongst companies, individuals and institutions that are able to support the development and implementation of these technologies and would be prepared to form a consortium that will be focused on the development and deployment of the technologies.

2 Table of Contents

3 Introduction

This document introduces a range of concepts and technologies currently being developed by Winwick Business Solutions in conjunction with others to address the urgent global crisis of climate change.

These technologies have the potential to either slow down the rate of climate change or, if deployed on a suitable scale, to reverse it. For optimal effectiveness with least downside, the solutions will need to be implemented as a combined suite of climate and ocean interventions.

The initiation of this project stems from a letter published in the Independent newspaper on the 8th January 2015 and co-signed by many of the world's leading climate change scientists. The letter made the front page headline on that day, under the title "*COP21: Paris deal far too weak to prevent devastating climate change, academics warn*." It is attached in Appendix 1 of this proposal.

The letter's message is stark. It warns that the COP21 agreement is deficient on many counts: its budgets are not legally binding and guarantee a temperature rise in excess of 2^0C by the end of this century and much more thereafter; it takes procrastination to a new level by introducing a five year delay to cutting CO2 emissions on the excuse of establishing a carbon budget for a 1.5^0C global temperature increase which will be unobtainable by the time the calculations are complete; most damning of all is that these temperature projections are based on successfully combining biofuels with carbon capture and storage (BECCS) in the vain hope that this will allow enough atmospheric CO2 to be drawn down in time to avoid catastrophic global warming. This concept is untenable at the planetary scale envisaged by the COP21 assessments. The inevitable failure of this solution will put the planet on track for a 6^0C temperature increase. This will lead to the extinction of most life forms.

The letter goes on to warn that the consequence of these political failures has been exacerbated by the rapidly increasing rate of climate change. Extraordinary heat waves hit the Arctic within weeks of the COP21's euphoric conclusion. These came on top of years of excessive warming. This combination makes a summer ice-free Arctic Ocean within the next few years highly probable. Without ice to reflect solar energy, a further dramatic increase in global warming will be unavoidable. Should this happen, it will release gigatonnes of methane from the permafrost and frozen seabed clathrates into the atmosphere, heralding the final phase of ecological collapse.

The crisis is now so severe that even an immediate transition to a zero carbon economy today would not guarantee avoidance of global catastrophe. However, COP21 has made it clear that under the current political framework there is no appetite for timely and effective action.

Humanity is thus left with no option but to start an immediate implementation of a climate intervention programme to restore ecological stability. To maximise the chance of a beneficial outcome and to minimise risk, this must be designed to work <u>with</u> nature to leverage the ability of existing natural processes.

This document outlines methods to do this and the business case that will support corporate involvement to achieve these goals. It is aimed at companies, institutions and individuals who can contribute to a coalition whose objective is to develop the necessary technology, manufacturing facilities, governance structure, and social licensing for an urgent roll out of climate stabilisation strategies and to develop the scientific rational behind these.

4 Objectives

4.1 Framework for the objectives

In relation to the response time of the global climatic system, the concentrations of atmospheric and oceanic CO_2 are undergoing a step change away from the equilibrium positions that had been maintained for millions of years by the planet's ecosystem.

This has led to the activation of many climatic and economic feedback loops. These are typically tightly coupled together, so that one feedback system can affect another, resulting in highly unpredictable results.

Examples of climatic feedback loops include methane eruption, ocean acidification, ice loss and ecosystem collapse. All of these lead to further amplification of the heating trend, otherwise known as feedback. Some, but not all of these feedback loops, are included in climate change models. However, even for those included, there is inadequate knowledge of their physics to ever allow accurate predictions of the outcomes with a suitable degree of certainty. Specifically, we do not know the size of the subsea methane clathrate reservoirs and existing computer models are based on highly simplified and conservative assessments of heat transfer from the warming oceans to these reservoirs.

As well as climatic and oceanic feedback loops, there are also economic activity feedback loops that are not captured in the climate change models. At present, economic activity is considered purely as an input to the climate change model through different Representative Concentration Pathways (RCP) with each one providing a different carbon burden. However, this is a gross simplification as it fails to acknowledge the intimate coupling between economic and ecological changes. Thus, as climate change intensifies then emissions are likely to be driven upwards due to the necessity to relocate flooded population and industrial centres and to develop military industrial complexes in response to increasing competitive stress. Finally, the fossil fuels needed to drive this will be of increasing carbon intensity as the Energy Return on Energy Invested (EROEI) will continue its deterioration as finite higher quality resources are depleted.

When these factors are combined, the world should prepare itself for abrupt climate change that could be on a time scale as short as a few years. In line with the precautionary principle of risk management, work on climate restorative technologies should start immediately. If not, humanity will not be able to organise appropriate responses against the background of social, environmental, financial and political dislocation that will follow.

It is the planning, testing, approving and implementation of this risk management strategy that forms the basis of the objectives for the proposal which follow below.

4.2 Specific Objectives

1. To identify and develop a suite of technologies that can be put in place within a few short years in order to forestall us from exceeding catastrophic global tipping points.

2. To identify the necessary capabilities for R&D, funding, global logistics, manufacturing and governance needed for rapid roll outs and to engage with companies and other institutions that are, or may wish to become, capable of providing these vital services.

3. To present viable models for their engagement.

4. To start the process of proof of concept and prototype testing

5. To establish a group with the critical knowledge and influence to start lobbying for national and international approval of rollout programmes for the technologies being developed.

6. To start lobbying for the establishment of global governance agreements and suitable administrative bodies for the various activities.

5 Technologies

The suite of technologies being considered are aimed at achieving the following three outcomes:

1. To increase marine cloud brightening (MCB) and thereby to increase planetary albedo (reflectiveness), cool given regions, and positively to influence regional precipitation.

   A prospective approach to marine cloud brightening is to use newly-developed fluidic oscillators to generate micro-sized bubbles of chosen sizes efficiently from sea-water. These will be formed on an aerostat (a lighter than air blimp) towed behind a ship at cloud-making height, or attached in arrays by power-lines to a moored wind turbine. On bursting, each microbubble creates a spray of even-sized brine nanodroplets designed optimally to seed and brighten clouds. These will serve the dual purposes of reducing global warming and of influencing where, when, and how much precipitation occurs downwind.

2. To increase carbon sequestration and restore oceanic biomass through ocean fertilisation.

   An approach to ocean fertilisation uses ultra-slow-release of the minerals necessary to increase phytoplankton growth in a safe and sustainable manner. This will be achieved by using lignin from straw to coat rice husks with the necessary minerals for phytoplankton growth. In so doing, it will overcome the mineral deficiencies now existing in the surface waters of the world's oceans and which acts as a limiting factor to carbon update. The missing nutrients are usually phosphorus, silica, iron and some other key trace elements. The resulting buoyant flakes are typically formed from mining wastes and low-cost renewable resources. They should provide food and habitat for small marine life for approximately a year before they disintegrate and sink. The initial mineral supplementation would allow nitrogen-fixers to proliferate in surface waters, thereby providing complete nutrient supplementation to the entire marine ecology. In the regions of methane hydrate emissions, special nutrient supplementation can be provided to methanotrophs to help them convert methane directly into biomass.

3. To increase ice thickness and coverage by pumping seawater onto sea-ice.

   An approach to thickening the ice cap would be to have a wind turbine and pump mounted on a semi-submersible platform. This assembly would pump sea-water onto existing sea-ice during the colder months where it would quickly freeze. In doing so, heat is radiated into space. It is estimated that the ice can be thickened by as much as a kilometre, most of which remains frozen over subsequent summers. As well as radiating excess heat, it also increases the planet's albedo. Furthermore the resulting cooling will stabilise the polar vortex thus mitigating extreme weather events and remediate polar habitat. By forming a waffled array of ice lenses, methane emitted from below can be trapped and either used as a marine food source or else harvested as a low-carbon fuel without having to drill for it. The ice can also be formed to a sufficient thickness to form barriers against warm water intrusion or glacial loss.

Details of each follow:

5.1 Marine Cloud Brightening

5.1.1 Basis of the concept

Seeding clouds with nucleating particles to induce rainfall has been practised for many decades, with mixed success. Seeding marine clouds in order to brighten them and thence provide cooling by reflecting more sunlight than otherwise is a more recent strategy in response to the threat and actuality of excessive global warming. More recently, it has been proposed to use seawater droplets, brine, or the salt crystals resulting from their evaporation, to nucleate clouds. Korhonen et al. 2010 indicate that MCB could have major net beneficial effects on global temperatures and precipitation.

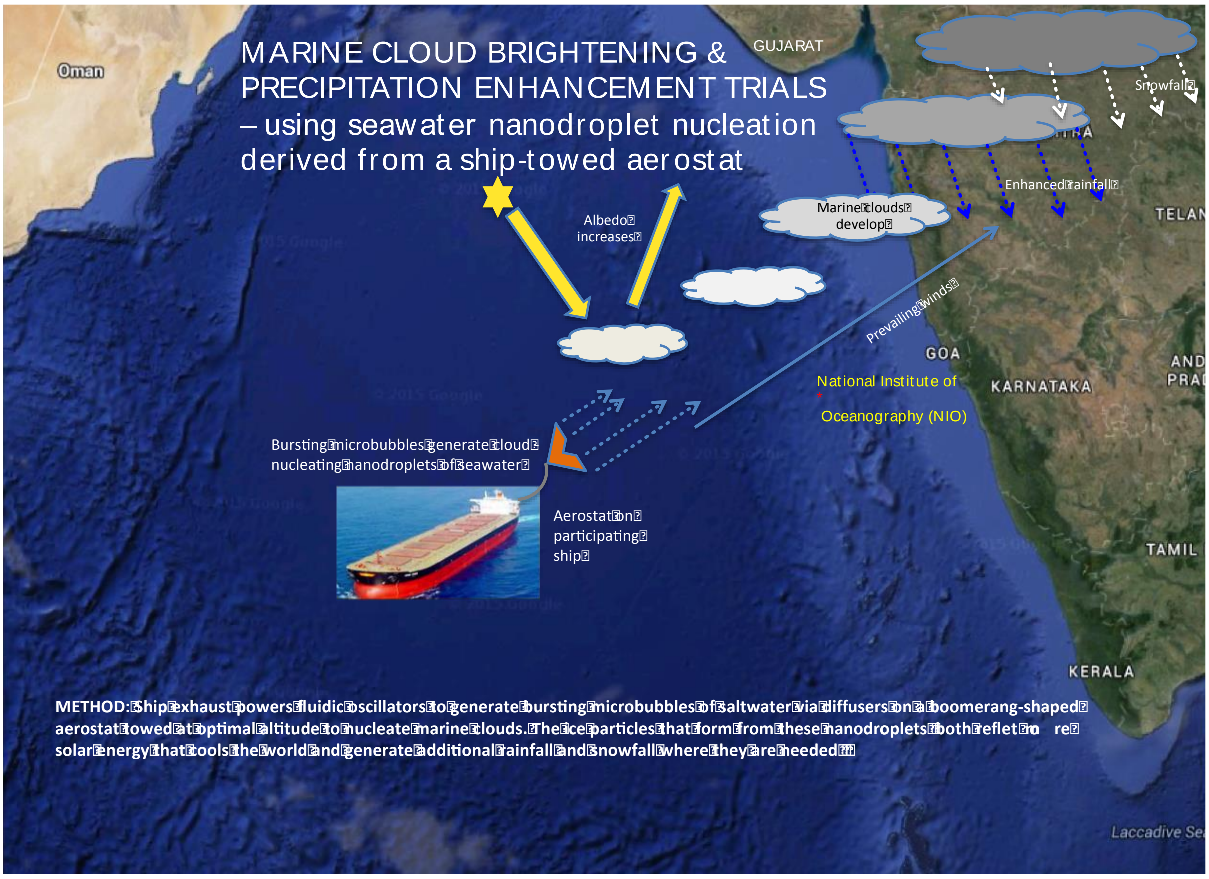

Figure 1 Marine Cloud Brightening concept

The effectiveness of this is dependent on using the seawater to produce sufficiently small particulates in substantial enough numbers to act as cloud condensation nuclei (CCN). To date, no technology has been demonstrated that can be deployed at the scale needed and quickly enough. This proposal describes an approach that can be deployed either on the back of existing ships or as fixed installations powered by a floating wind turbine. The approach described is energy efficient, is basically low-tech, and uses existing manufacturing processes. It replicates what nature does by using ocean spume as the free, and inherently non-polluting active material. As such it meets the requirements of being economical, scalable and quick to deploy.

The key technological breakthrough to enable this has come from the UK development of the fluidic oscillator (FO). This device has no moving parts to wear out. It has a lightly-pressurised gas supply inlet going initially into a single channel which forks into two separate channels. Immediately before the separation is a feedback control loop, shown in the schematic below as the upturned U. As the moving stream of gas flows through the neck, it preferentially attaches to one side and one outlet. Once it does this, it creates a small area of low pressure at the opening to the U channel which sucks gas in from the other side. This reduces the pressure on the other side until flip-over occurs. The process then repeats in the opposite direction, thus setting up a highly regular and intense oscillation. The result is a pulsed gas outlet from both nozzles. A typical output is shown below in the following diagram.

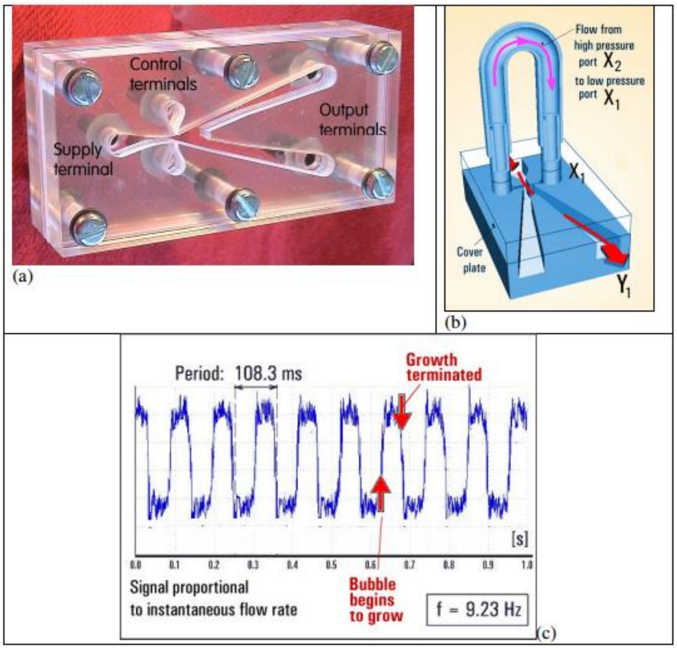

Figure 2 General configuration of the fluidic oscillator

The gas output from the fluidic oscillator is fed into two separate feet, each of which has pores that allow the gas to pulsate into a thin film of brine in a groove. For MCB purposes, the actual pore dimensions will be approximately 4 microns in diameter. By appropriately alternating their position with a 3 pore diameter spacing, there would be approximately 1 million laser-drilled pores per square centimetre of groove base. On bursting in the wind, each microbubble tends to project four, jet nanodroplets orthogonally from the brine surface, each being approximately the same size. Hence, each square centimetre of diffuser could theoretically produce 700 million cloud-nucleating nanodroplets per second at 200Hz. In actuality, though some losses will be expected, it represents the most efficient and safe way of nucleating clouds.

It is the oscillatory regime in the fluidic oscillator that determines the bubble size and keeps them sufficiently small. The bubbles formation starts at the onset of the upwards cycle of the sine curve and terminates shortly on the downwards one. The bubble size is thus determined by the frequency and amplitude of the oscillations and is thus highly controllable.

This FO approach contrasts with the normal process of an aerator where pressurised gas is blown through a porous manifold. This is energy intensive, prone to blockages and does not provide the uniformly small sized particles.

Because the operating gas pressure in the FO is modest, weight can be minimised. This makes the system suitable for installation in an aerostat that can either be towed behind a ship, or moored in the wind, and operated at an optimal altitude.

The gas source to the fluidic oscillator may be a relatively small bleed from the hot exhaust gases of the ship's engines. These are cycloned to remove soot particles and then possibly pressurised further to allow the reduction of delivery pipe diameter. Each FO outlet is attached to a manifold pipe that is positioned approximately half a millimetre under the base of a small, brine reservoir of groove form. The reservoir is replenished via pressurised pipe using the ~17% salt brine left over from the operation of the ship's water-maker, or from seawater. The fine microbubbles are generated in this groove. As these rise and burst in the wind, they release jet nanodroplets of brine that nucleate clouds. It is this final step that both increases cloud albedo and seeds additional clouds when released into air that is supersaturated with water vapour.

As the CCNs can be finely controlled by the frequency and distribution of the FO, then two or more different sizes of nanodroplets can be produced to deliver more than one outcome, such as simultaneously influencing precipitation and albedo in a cloud.

Artificial intelligence (AI) may be used to control most of the operation, including the aerostat's helical path to achieve zone-wide dissemination, leaving only the operating parameters to be input or changed by a human controller.

UK Sheffield researchers have already applied such microbubbles to isothermal distillation, whereby the bubbles are produced from warm (typically waste) gas entering a thin film of liquid thus validating the first stage of the concept.

5.1.2 Ship based installation

The MCB can be performed either from the back of ships as they go about their normal business or by using ships specifically chartered for the purpose. Integration of the MCB technology onto a ship would be relatively simple and follow a design philosophy of keeping things simple and robust whilst largely using existing technology.

The diagram below shows the basic schematic and interconnection of the main components.

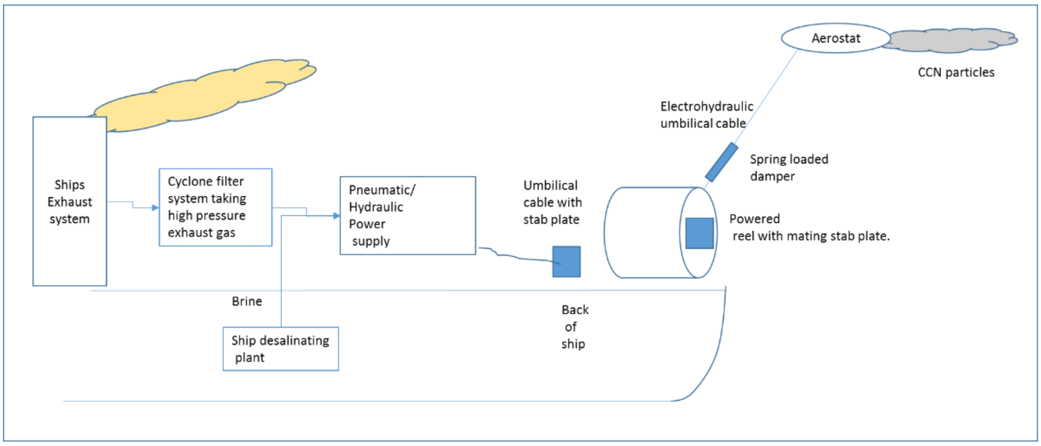

Figure 3 Ship-based interfaces

The key elements of the system are:

1. Ship mounted hydraulic power pack - this will be used to pressurise the brine solution for pumping to the required height and to maintain the required flow rates.
2. Electrohydraulic umbilical cable mounted on an electrically powered reel. The umbilical will be deployed from this to the required height and then locked in position. Once this is done, an electro-hydraulic umbilical stab plate is used to manually make the connections to the cable. The umbilical will contain a pneumatic cable for the cleaned exhaust gases, a hydraulic cable for the brine, an electrical cable for control and power. An outer casing of plaited, fine, titanium wire may also be needed for strength and lightning protection. The umbilical when fully charged will be the heaviest item to be lifted by the aerostat and will determine the size and shape of the aerostat needed. To minimize weight and wind resistance, the intent will be to run the hydraulic line attached to the inside of the pneumatic line, with the gases travelling in the crescent gap between them.
3. The aerostat will be designed around two possible configurations. The first option being considered is a lighter than air body using either helium or hydrogen and shaped in an aerofoil configuration. The diffusers will be located along the length of the upper surface. The second option will again be a lighter than air body, but this time the hydrogen or helium will be stored in inflatable tubes which can be rotated to make use of the magnus effect to provide additional lift.
4. When necessary, hydrogen can be sent to tubular cores in the aerostat to recharge it using the pneumatic line with two-way control values at either end.
5. It is intended to use concentrated brine from the ships desalination plant as the feedstock to the diffusers. This significantly reduces the volume of fluid that needs to be pumped to the aerostat. Initial calculations suggesting that this can reduce energy requirements by a factor of up to seven. At the same time, the high salt concentration will allow for better CCN.
6. Cyclonic cleaners will scrub carbon and other particulates from the exhaust. The cleaned gas will be pressurised and while still warm transmitted to the aerostat. The SOx content of the exhaust will improve nanodroplet cloud nucleation capability still further, whilst returning most of the SOx to the sea where it can be utilised by phytoplankton.
7. The aerostat will be towed behind the ship at a suitable height (typically 1-1.5km) to optimise cloud nucleation. Standard electro-hydraulic relief valves control liquid and gas pressures to the diffusers and the fluidic oscillators. It will be designed to be foldable for ship storage and on deck handling.

5.1.3 Wind Turbine based installation

The fluidic oscillator method of MCB can also be deployed on a fixed and semi-permanent basis by using a floating offshore wind turbine to power a buoyed and moored array of aerostats.

The configuration will be similar to that of the ship mounted system. The main other difference is that, if a desalination plant is to be used to generate brine and potable water, rather than just using filtered seawater, it would be mounted at the base of the wind turbine. If the system is located near populated coastal regions, then it can also be used to provide fresh water for piping ashore. Such a system might also generate hydrogen by electrolysis for both aerostat replenishment and fuel sale. Stored hydrogen might be used for back-up fuel-cell power for island communities when solar and wind power were insufficient or unavailable.

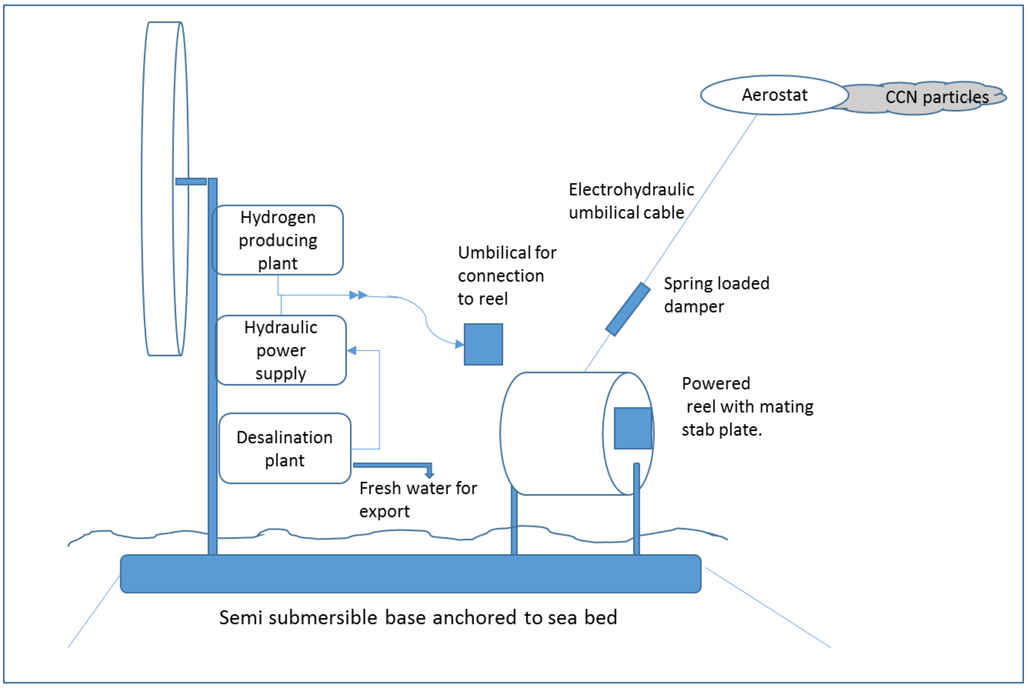

Figure 4 Wind turbine interfaces

5.2 Carbon Sequestration through ocean fertilisation

Increasing phytoplankton growth through ocean fertilisation with iron-rich compounds has been considered as a response to climate change since the 1980s. Since then, various experiments have been carried out, with modestly positive results. One of the most significant of these was in the Antarctic Ocean in 2004 when Smetacek and his colleagues dropped 5 tonnes of iron sulphate and saw a 65-square-mile bloom of phytoplankton. Their reports indicated that some of "the phytoplankton sank like a stone to the bottom of the ocean." However since then, it has been thought that the monitoring did not occur for nearly long enough to reveal the full extent of carbon-sequestration and biomass increase caused by the experiment.

The effectiveness of these experiments to deliberately fertilise the oceans with vital minerals contrasts with the far wider global 'unintended experiment' of industrial fishing and whaling that has been ongoing since the advent of the whaling age. This has inadvertently denuded the ocean surface waters of vital minerals while systematically stripping the ocean of much of its life and biodiversity. It has substantially degraded most of the marine ecosystems on which the health of oceans and the planet depends.

The unintended consequence of this is that the oceanic stocks of critical nutrients that supported the base of the marine food chain have been lost. This makes a recovery of the ecosystem difficult and it limits the oceans' ability to sequestrate CO2 at the time when it is needed the most. Whale excreta, for example, provided a key role in cycling nutrients from the deep sea to the ocean surface. In turn, this allowed phytoplankton to thrive in the sunlit upper layers of the ocean and thereby maintained the food chain. The overfishing and whaling disasters of the past 300 years was, in effect, a strip mining exercise of the ocean's critical resources that had bioaccumulated in these species and their prey.

The potential of restoring the ocean mineral balance on a global scale was confirmed with the eruption of Mount Pinatubo in the Philippines in 1992. It is estimated that it deposited approximately 40,000 tons of iron and silica-rich dust into the oceans worldwide. The subsequent global phytoplankton bloom temporarily stabilised rising atmospheric CO2. This effect can be seen in the CO2 measurements from the Mauna Loa observatory as a flattening of what is otherwise a steady, exponentially increasing trend. The fact that this happened despite the accompanying huge CO2 emissions from the volcano itself and other significant events at the same time, such as the deliberate setting on fire of oil wells during the First Gulf War, makes it an even more remarkable result. It is reported that as well as atmospheric CO2 temporarily stabilising, atmospheric oxygen levels also increased, presumably as a result of increased photosynthesis.

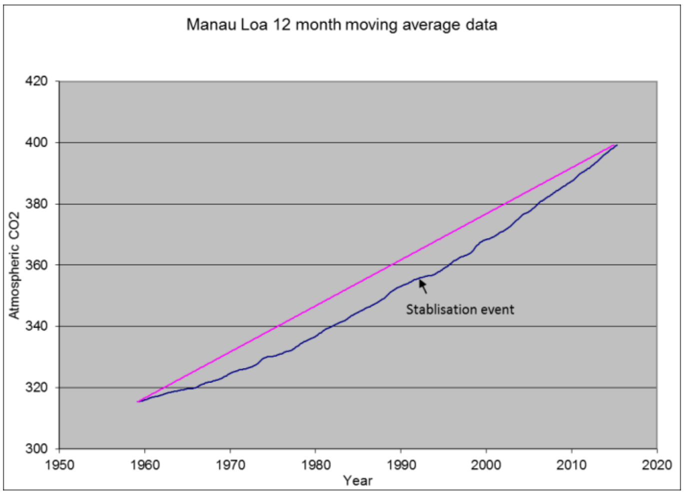

Figure 5 Manu Loa Moving average CO2 data showing Mount Pinatubo effect

This stabilisation of atmospheric CO2 also occurred without any major detrimental effects to the oceans.

Despite the evidence from this, objections to ocean fertilisation as a solution to climate change still continue. A key focus of these is the risk that large additions of nutrients could cause boom and bust population cycles of phytoplankton which might destabilise delicate oceanic balances. Detractors often point to examples such as the plankton blooms in places such as the Gulf of Mexico which have been triggered by excess industrial fertiliser runoff coming down the Mississippi.

There are also practical limitations with the traditional approaches to ocean fertilisation. The most basic problem is that the beneficial effects are of a short term nature. This was demonstrated by the trials and even to a large degree by the Mount Pinatubo event. It is due to much of the added iron-rich mineral sinking quickly before the ecosystem had chance to benefit fully from it. Traditional iron fertilisation using soluble, commercial, and non-buoyant fertiliser is unlikely to be a feasible solution to climate change as ships would have continuously to ply the oceans making roughly fortnightly additions to all areas of nutrient-deficient ocean, and in which perhaps more than 90% of the fertiliser would be wasted to the dark, cold depths. Furthermore, many areas of ocean surface are deficient in phosphorus, silicon and selenium, amongst several other trace elements. Supplementary iron only benefits some surface waters at some times. Complementary nutrients are required for most ocean areas, else the iron is largely ineffective.

To address these issues, we propose an approach that will maximise the effectiveness of any mineral addition and believe that testing and development of this technology should start immediately.

The solution is to have ultra-slow release of the deficient minerals into only the surface waters of the marine environment in the open oceans. This will be achieved by adhering the necessary minerals with hot-melt lignin to buoyant rice husks. The mineral selection will be optimised for a given location to maximise phytoplanktonic growth. The nutrient release from these will take many months, thus keeping the risks of over-fertilisation, eutrophication and toxicity at either a minimal or non-existent level.

The minerals would be mainly phosphorus, iron and silica sourced mainly from mining wastes, and which sometimes fortuitously include other key trace element nutrients. This mineral supplementation would allow nitrogen-fixers to proliferate in surface waters, even though the waters will become increasingly stratified under global warming. Furthermore, in regions of methane hydrate emissions, this supplementation could be tailored to the specific trace elements needed for methanotrophic (methane eating) bacterial growth, thus allowing fine-bubble methane to be converted into biomass before it reaches the surface.

All the materials necessary are available in large and sustainable quantities today.

Figure 6 Rice Husk hill

The rice husks are a by-product of the harvesting and winnowing processes that separate the grains of rice from their bran and husks. Typically, husks are packed into large bags at the mill, though they can also be transported in bulk. Because of their low density, and hence large volume, they are expensive to transport. Because of their high silica content, low food value, abrasiveness, and resistance to compression for transportation purposes, they are also difficult to find profitable uses for, except as animal bedding or as low-grade and heavily-slagging boiler fuel. They are only just beginning to have minor commercial use in the production of cellulosic ethanol and other chemicals. Even their landfill disposal tends to be difficult and costly, particularly as it may also soon attract emissions charges on top of disposal charges. The available and sustainable yearly resource of waste rice husks approximates 100m tonnes.

The fertiliser can be made from mixed, ground-up, low-grade ores which are uneconomical to refine or from processing wastes. One valuable source that is already available in 'powdered' form is the iron and silica-rich red mud waste left over from alumina refining. This alone should be sufficient for many fertilisation purposes. Another source phosphatic clay remaining after the extraction of commercial fertiliser. These wastes have no other useful purpose. There are 1.5Gt of them now in waste piles, with more being produced each year. They are finely divided, if moist and are relatively rich in all the required nutrients, including selenium that phytoplankton use in photosynthesis.

Figure 7 Red mud from alumina refining

The third component of the buoyant fertiliser flakes is the glue that will bind the fertiliser onto the rice husks. For this, the most abundant, renewable, cheap and durable glue that there is on Earth will be used: lignin from plants. Today, the costs of lignin are in decline, due to the development of better industrial separation methods for lignocellulosic material and the global proliferation of biorefineries designed to produce sugars, alcohols, biofuels and chemicals from them. Lignin sources include sugarcane bagasse, corn stover, cereal straw, energy crops, wood, forestry and pulpmill wastes. These, or their lignin by-products, are often still just burned to produce local power or heating. Higher grade uses than lignin's current ones are emerging, as some lignin is now being used to form carbon fibre, nanocarbon products and chemicals. Overall, the development of lignin as a major industrial input should help to keep the price of lignin within bounds, whilst increasing its quality and availability. Current global lignin production (much of which is in the less-useful lignosulphonate form) is around 45Mt/yr. Pure lignin production is expected soon to rocket as the biorefinery industry and the use of waste and purpose-grown biomass blooms.

The rice husk fertiliser platforms (the buoyant flakes) are easily made, possibly at the transit or aggregating ports to which the raw husks are delivered. Typically, the husks would require little or no pre-treatment, though flattening by hot-rolling with rice water glue would reduce transport costs.

When scattered pneumatically over the sea surface, each flake becomes a tiny, green, floating farm. The algae, diatoms and other phytoplankton on the farms are grazed upon by tiny herbivores, which are in turn eaten by zooplankton, crustaceans, molluscs and fish further up the food chain. The expanding ecosystem which results sequestrates carbon from its environs, some of which sinks as excrement, carbonaceous shells, or dead organic matter.

As well as sequestrating the carbon, this approach has five other key benefits:

1. The dark blue of the less-productive high seas is replaced with the lighter turquoise hue of productive seas, thereby cooling the world by reflecting more solar energy back into space.
2. Chemicals released by the additional phytoplankton contribute to marine cloud brightening, thereby also increasing global albedo fairly evenly and hence reducing diverse regional effects.
3. The additional photosynthetic phytoplankton offset ocean acidification by converting the carbon dioxide dissolved in the ocean surface waters (carbonic acid) into neutral biomass and oxygen;

4. Part of this resulting biomass will sink at the end of its natural life, taking carbon from the ocean surface with it and leaving these same surface waters able to absorb more atmospheric CO_2.
5. Increasing fish harvests as the enriched base of the food chain supports larger, more productive and diverse stocks.

5.2.1 Immediate steps and concept testing.

It is envisaged that the fertilisation process would be scaled up following initial laboratory and ocean trials under different conditions. During this period, the scale and concentration of the flake disseminations can be increased as confidence grows.

This requires careful monitoring over a prolonged period to establish the longevity of the flakes, the effectiveness of the fertiliser delivery, and related outcomes. The legal position of both authorisation to disseminate flakes and to establish licensing rights over fish taken within a managed area will need to be established by protocol. The third thing to establish is the ability of such a method to sequestrate carbon in a way that attracts saleable, carbon credits and to determine what level of credit is due.

5.3 Ice cap thickening and ice shields

The third aspect to this climate remediation strategy is to thicken the polar sea ice.

It is proposed that this be done first by locating wind turbines in the Arctic Ocean on moored, semi-submersible platforms. Over the winter period, these will be used to pump water from below the sea-ice sheet onto the surface. This will form a thermal bridge where part of the water will then freeze in the colder air. The ice sheet will then thickening into a lens shape, the top and bottom of which is in cone or reflected-cone shape, analogous to that of a volcano-formed mountain.

Wind turbine power left over from ice shield construction can be used to export electrical power through a high voltage direct current (HVDC) cable laid on the formed ice road and then protected with additional ice cover.

The diagram below shows a single pump attached to a wind turbine. However, the wind turbine could be used to power several pumps in an array around it. Each pump and seawater pipe can be located on its own platform creating an array of ice thickening points. The individual ice shields can be connected by ice to generate ice sheet arrays connected to land that could cover all polar regions, less corridors.

In shallow water an "ice mountain or range" could be created which eventually beds itself on the sea floor so that it does not move. Arrays of these could be used to plug methane hydrate vents and act as dams against warm ocean currents. At the same time, regional thickening would maximise albedo and the waffled form of the arrays could be used to trap and harvest any fugitive methane emissions.

Such sea-ice could be thickened by up to a kilometre, thereby making the ice arrays semi-permanent. When firmly grounded, they could resist glacial movement, ice tongue melting and break-up.

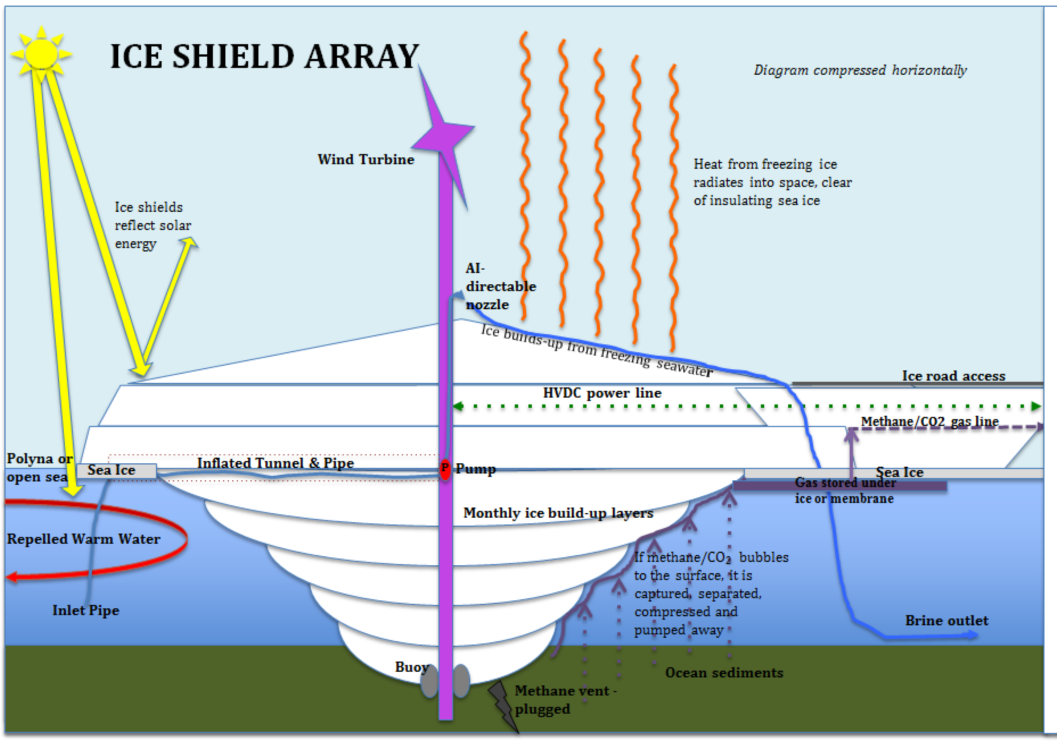

Figure 8 Ice sheet thickening

This technology should provide the following outcomes:

1. The planet's albedo will be increased and heat from the sun will be prevented from being absorbed by the parts of the polar oceans that are so protected.

2. This approach removes heat trapped in water under the insulating Arctic Ice. The system acts as a series of giant heat pumps which transfer oceanic heat to the surface where it can be radiated out into space.

3. The pump would remove the warm water that would is currently destabilising the frozen methane clathrates on the sea bed.

4. The approach can be quickly deployed to areas where methane clathrates are identified at being at risk. These vary in depth below the sea bed and are subject to destabilisation by warm ocean currents, sediment slippage and the creation of vents. The flexible approach of the proposal allows targeting of responses to places where the time taken for heat to transfer from the ocean to the methane reservoirs turns out to be far shorter than anticipated in models.

6 Combined applications

The effectiveness of the above techniques can be maximised when deployed in co-ordination with each other.

Typical co-ordinated activities would be:

1. Marine Cloud Brightening could be deployed in the Caribbean region as well as the tropical and sub-tropical areas of the Atlantic Ocean. This would reduce the heat being absorbed by the surface waters there that would normally exacerbate extreme weather events in the Americas and Europe and transfer warmth to the Arctic by the Gulf Steam. In polar regions sea-ice thickening could be employed with a higher chance of success given that the heat transfer to this region is already being reduced by MCB.
2. Ocean fertilisation can be deployed in the remote regions of most oceans to increase marine populations and reduce acidification. Where methane venting is a concern, special nutrients in the flakes can be included for methanotrophs to increase their beneficial effects.
3. Coral regions around the world are bleaching and dying under the combined influence of rising sea temperatures and acidification. Marine Cloud Brightening upwind of the corals would help cool these. If done with tailored fertilisation far up-current of the corals this could increase phytoplankton growth and help to reduce acidity. Restoring the health of corals, if successful, could provide a step change in the carbon sequestration ability of the oceans.
4. If Marine Cloud Brightening is done in large areas of the Pacific, then it may be possible to cool a sufficient body of surface water to re-establish the ocean circulation currents that are currently under threat by warmer, low density water settling on the ocean surface. If done in conjunction with fertilisation, then the resulting biomass is more likely to taken to taken to deep, cold oceanic depths for long periods. Modelling has already demonstrated that with atmospheric CO_2 at 450ppm then the ocean circulation system will effectively stop due to the lower density warm water settling on the surface.
5. Selective MCB can also provide us with influence over downwind precipitation, that can then increase glaciation and reduce soot-assisted melting.
6. Cooling the Arctic by these three methods in cooperation would serve to stabilise the Polar Vortex, thereby helping to restore climate and habitat in the Northern Hemisphere.

7 Business case

The purpose of this part is to start the process of identifying key individuals, companies and institutions that would be willing to be members of a consortium that can support the research and development necessary to progress and gain approval for the concepts outlined in section 4 above, as well as being able to provide the seed funds and adjudicated trial outcomes necessary to attract bulk funding for those technologies that passed the tests.

This same consortium would also develop the logistics and industrial manufacturing facilities to enable a quick and co-ordinated rollout in the event of either a decision being made to start climate intervention or when abrupt climate change becomes so severe that it is clear that no other reasonably safe, effective, feasible and better overall options are available.

The consortium may take the eventual form of an NGO, a not-for-profit organisation, a charitable trust, or a loose association. This is yet to be decided. Most of the intellectual property is already licensed under Creative Commons International Attribution 4.0 and is thus free for all to use, with acknowledgement.

The reasons why companies and individuals would want to be part of this follow:

1. The technology developed by the consortium will be shared within the consortium. Member companies and individuals would have first right of access to this and to exploit it. As these technologies are critical to survival of life on the planet in the event of runaway climate then it is the intent that the intellectual property rights for their application to climate remediation will be shared and no patent restrictions will be imposed. However, first mover advantages, including garnering access to key resources and services, will still apply.

2. Once climate change develops as predicted, nations will be forced to implement climate intervention strategies for survival. These may have to be funded through carbon credits or direct payment by governments or international bodies such as the UN. Companies that join this consortium will be at an advantage to capitalise on this new market.

3. We also note that $100 billion per year is to be set aside for mitigation and adaptation to climate change in the developing world. When temperature rises much above 2^{0}C, no amount of expenditure will provide adequate adaptation, thus this money would be wasted and become merely a token political gesture. We will thus lobby for a significant proportion of it to be diverted towards climate intervention. This is likely to be a far more timely and effective use for it. As the consortium's strength increases and its technologies are developed and proven to work, increasing diversion will become more achievable.

4. We will extend associate membership of the consortium to leading climate change scientists and thinkers. Their input is vital to the validation of proposals; but also companies that commit to it will have first-hand access to climate remediation knowledge that can inform development of their business strategies in a rapidly changing and uncertain world.

5. We believe that funding direct intervention will be of interest to the re-insurance industry. This industry will be first in the firing line from the impacts of abrupt climate change and is collectively at risk for trillions of dollars of damage. This cost is far in excess of that needed to deploy the technologies listed above.

6. Perhaps most importantly, there are altruistic reasons to join. Normally this does not make for good business sense, though it can be reputationally beneficial. However, the scientific community is increasingly recognising the risk of even more abrupt climate change. Should this happen, there will be no time to develop new technologies, so solutions must be available off the shelf. Furthermore the normal ideals of companies existing to maximise long term shareholder return will be redundant as society will be plunged into a battle for individual survival. From this perspective, it is in the best interests of companies to start co-operating in the development of climate restoration technologies that can be rolled out without payment and without concern to give them replacement revenue. This is analogous to the building of lifeboats that are to be released from a sinking ship. Today, we have no lifeboats, but we do have a ship – our planet. It is a ship that we share with all other life on Earth and we have an obligation to save it! After activating a viable planetary survival strategy, companies could then return to optimising their long term profitability, including possibly those from these and other restorative, yet still patentable, technologies now in the pipeline.

8 The letter

The hollow cheering of success at the end of COP21 agreement proved yet again that people will hear what they want to hear and disregard the rest. What people wanted to hear was that an agreement had been reached on climate change that would save the world while leaving lifestyles and aspirations unchanged.

What they disregarded were the potentially deadly flaws lying just beneath its veneer of success. As early as the third page of the draft agreement is the acknowledgment that its CO2 target won't keep the global temperate rise below 2 ^{0}C, the level that was once set as the critical safe limit. The solution it proposes is not to agree on an urgent mechanism to ensure immediate cuts in emissions or negative emissions, but to kick the can down the road by committing to calculate a new carbon budget for a 1.5^{0}C temperature increase that can be talked about in 2020.

Given that we can't agree on the climate models or the CO2 budget to keep temperatures rises to 2^{0}C, then we are naïve to think we will agree on a much tougher target in five years when, in all likelihood, the exponentially increasing atmospheric CO2 levels mean it will then be too late for effective action.

More ominously, these inadequate targets require humankind to do something much more than cut emissions with a glorious renewable technology programme that will exceed any other past human endeavour. They also require carbon dioxide to be sucked out the air and sea. The currently favoured method is to out-compete the fossil fuel industry by providing biomass for power stations. This involves rapidly growing trees and grasses faster than nature has ever done on land we don't have, then burning it in power stations that will capture and compress the CO2 using an infrastructure we don't have and with technology that won't work on the scale we need and to finally store it in places we can't find. To maintain the good news agenda, all of this was omitted from the agreement.

The roar of devastating global storms has now drowned the false cheer from Paris and brutally brought into focus the extent of our failure to address climate change. The unfortunate truth is that things are going to get much worse. The planet's excess heat is now melting the Arctic Ice cap like a hot knife through butter and is doing so in the middle of winter. Unless stopped, this Arctic heating will lead to a rapid release of the methane clathrates from the sea floor of the Arctic and herald the next phase of catastrophically intense climate change that our civilisation will not survive.

The time for the wishful thinking and blind optimism that has characterised the debate on climate change is over. The time for hard facts and decisions is now. Our backs are against the wall and we must now start the process of preparing for geo-engineering. We must do this in the knowledge that its chances of success are small and the risks of implementation are great.

We must look at the full spectrum of geoengineering. This will cover initiatives that increase carbon sequestration by restoration of rain forests to the seeding of oceans. It will extend to solar radiation management techniques such as artificially whitening clouds and, in extremis, replicating the aerosols from volcanic activity. It will have to look at what areas that we selectively target, such as the methane emitting regions of the Arctic and which areas we avoid.

The high political and environmental risks associated with this must be made clear so that it is never used as an alternative to making the carbon cuts that are urgently needed. Instead cognisance of these must be used to challenge the narrative of wishful thinking that has infested the climate change talks for the past twenty one years and which reached its zenith with the CO21 agreement. In today's international vacuum on this, it is imperative that our government takes a lead.

Signed by

Professor Paul Beckwith, University of Ottawa

Professor Stephen Salter – Edinburgh University

Professor Peter Wadhams – Cambridge University

Professor James Kennett of University of California.

Dr Hugh Hunt – Cambridge University

Dr. Alan Gadian -Senior Scientist, Nation Centre for Atmospheric Sciences, University of Leeds

Dr. Mayer Hillman - Senior Fellow Emeritus of the Institute of the Policy Studies Institute

Dr. John Latham – University of Manchester

Aubrey Meyer – Director, Global Commons Institute.

John Nissen - Chair Arctic Methane Emergency Group

Kevin Lister - Author of "The Vortex of Violence and why we are losing the war on climate change"