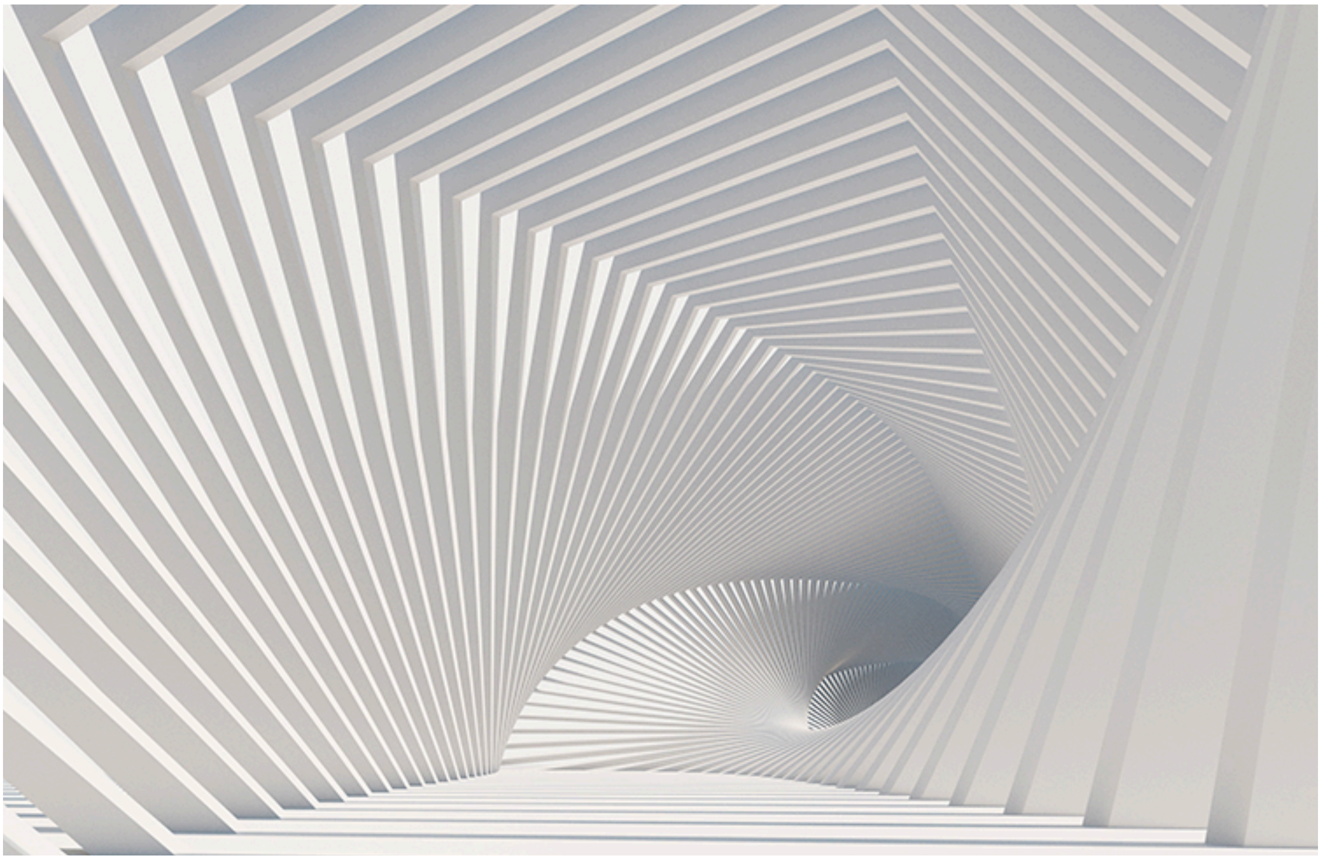
INVENTING OUR FUTURE

BY SEV CLARKE, JULY 2024



Introduction

By 2030, we will either have effectively begun to address global warming, sustainability and a livable, biodiverse planet into the future, or we will have fully entered an unavoidable, dark and downwards spiral. This document, and the conceptual inventions it outlines, suggests some of the key means by which we can traverse the brighter path.

My journey to this point started long ago. If any single starting point can be adduced, perhaps it was in the Ash Wednesday Bushfires that ravaged the State of Victoria in 1983. Fighting one of them on the back of a makeshift fire tanker in Mt. Macedon made me realise (subsequently) that the climate was changing, that we were causing it, and that only our collective efforts could prevent Armageddon. The inventions described below are my attempt to help us escape the Tragedy of the Commons that otherwise we may henceforth endure - or fail to do so - alongside the other wonderful species that share our planet and on whose ecological services we all depend.

The Inventions

These fall into, perhaps, two broad categories: those that directly address climate change and those that seek to improve some of our industrial processes and resource limitations. None have been tested, developed, shown to be effective, or approved. Only a few are under investigation by research agencies. Doubtless some will be found wanting, or for which better solutions will be found to the problems they purportedly address. A peer-reviewed paper has been published by Oxford Open Climate Change that includes four of the climate change solutions that I propose, see https://academic.oup.com/oocc/article/4/1/kgae014/7731760?utm_source=substack&utm_medium=email&login=false . The first of these, Buoyant Flakes, is currently being investigated by an international consortium of five research agencies with promising early results.

Invention List

CLIMATE CHANGE SOLUTIONS

Buoyant Flakes - Ocean fertilisation to regenerate marine biomass, biodiversity & cooling
Seatomisers/ISA - Seawater atomisation to brighten the skies and remove atmospheric methane
Fiztops - Nanobubbles to brighten the ocean surface
GasGuzzler - Extracts carbon dioxide and acidic vapours from flues and natural gas
Ice Shields - Ice Thickening to brighten and restore cryogenic habitat

INDUSTRIAL PROCESS IMPROVEMENT

Turquoise Hydrogen - Generates emissions-free hydrogen from methane
Pure Carbon Products - Crystallises graphene and carbon products from methane splitting
Winwick Supercapacitors - Should replace large chemical batteries and some transport fuels
Fluidic Oscillators - Existing Perlemax technology efficiently generates monodisperse bubbles
PET/Ti foil diffusers - Should markedly improve fluidic oscillator and fermentor performance
Laser Spalling and Drilling - Should allow economical construction of large drillhole reactors
Winwick Drillhole Reactors (WDR) - Should allow major advances in hydrothermal chemistry
Winwick Photobioreactors (PBR) - Should allow efficient, terrestrial microalgaculture

SOME CLIMATE CHANGE SOLUTIONS

BUOYANT FLAKES

Short Description

Previous attempts to farm the sea or to increase oceanic carbon sequestration have used soluble, artificial chemicals that do not remain near the surface. However, long-lived, ultra-slow-release buoyant flakes can be disseminated annually by ship over selected ocean areas. The tiny flakes are comprised of natural, organic materials and mineral wastes. Like a self-feed system, these do not so much release the nutrients to the environment, as to make them available at the sea surface where the phytoplankton which need them can 'suck' them out of the seawater, or the exposed mineral particles in the flakes, using their transporter enzymes, or ligands. Thus, there is little chance of either over-fertilisation, eutrophication, toxicity, or of the nutrients being lost rapidly to the dark depths. For iron-rich nutrient, being at the surface allows UV light temporarily to transform/reduce the less-soluble ferric form into the more soluble ferrous form, thereby aiding its metabolisation into phytoplankton biomass.

The foundation of each flake is a single rice husk, rich in the opaline silica needed by diatoms. Glued to this by plant-derived lignin hot-melt glue is a sealed matrix of gas and minerals designed to provide phytoplankton communities with whatever nutrients are wanting in that part of the ocean. As dark blue ocean waters are deficient in one or more macronutrients or trace elements (typically phosphate, iron, silica and transition metals - reactive nitrogen nutrient being able to be made from air by diazotrophs), using buoyant flakes could turn these blue or 'desert' ocean regions into productive, turquoise seas. Substantial sources of already finely-divided and stored nutrients are the red mud residual to alumina refining and the phosphatic clay wastes residual to phosphate extraction. Atomised, rice water glue with dissolved urea leavening agent is used to adhere the mix of lignin powder and minerals robustly to the husks, followed by baking to melt the lignin and gasify the matrix, thereby forming durable, buoyant pellets. These are to be delivered pneumatically from bulk ships to oligotrophic ocean surfaces, typically annually.

Krill and most other diel vertically migrating (DVM) species consume phytoplankton in surface waters at night, then respire and excrete the carbonaceous wastes in the dark, safer (from visual predators) depths of up to a kilometre during daylight hours, thereby sequestering its carbon content.

The nutrient mix can also be adapted to suit methanotrophs (methane eaters) present in water or soil, such as are found in melting permafrost, seabeds, oceans, lakes, swamps, rice paddies, termite mounds, landfills, fracking & mining operations, abandoned mines & gasoil wells, and feedlots.

Key Functions

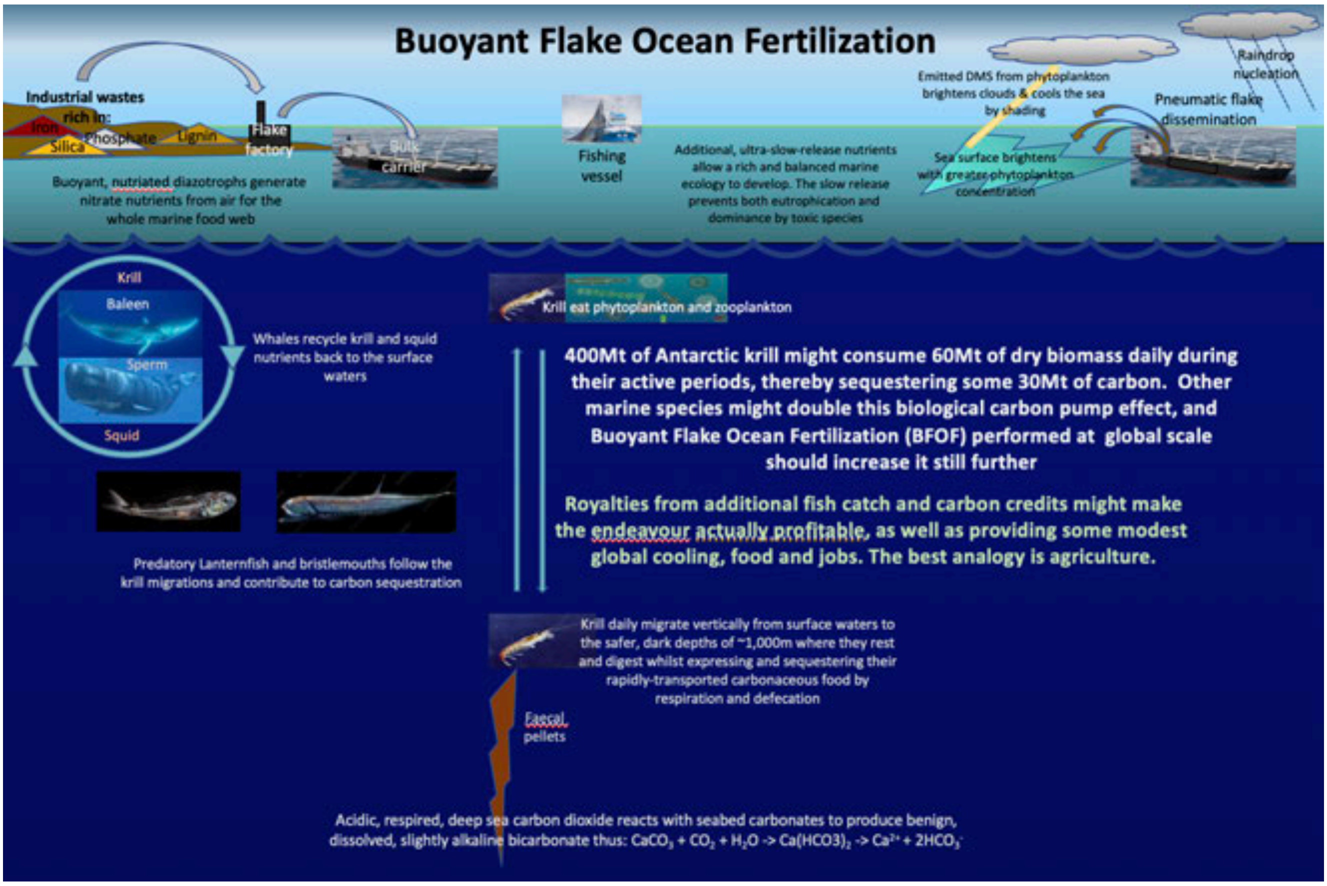
Increases oceanic albedo; increases the biomass and biodiversity of aquatic life; sequesters atmospheric carbon dioxide (CO_2) securely as carbonaceous seabed ooze & rock, refractory dissolved organic carbon (DOC), and benign, dissolved, alkaline bicarbonate; increases oceanic albedo (reflectiveness) that cools the surface waters; increases atmospheric DMS aerosols that nucleate or brighten cooling marine clouds.

Innovation Dependencies

None known.

Extensive supporting documentation is available at https://www.noac.info/ReferencesDetail.aspx

Graphic



SEATOMISERS/ISA

Short Description

Anchored, offshore wind turbines could be used to power satellite, mast-like units that spray filtered seawater of different particle size ranges from three spars into the lower atmosphere. The spray nozzle assemblies on the lower two spars are designed to spray humidifying droplets that partially evaporate to form cooler, moisture-saturated air and brine droplets that fall back into the sea before they reach land. These should be able to help make new cloud where none currently exist, as well as to thicken existing marine cloud. The nozzles on the lowest spar, which produce the largest microdroplets, would typically be activated only in high winds when the power supply is plentiful. Changing the nozzle pressures could be used to determine the modal size of droplets produced and how far they would carry downwind under forecast weather conditions.

Coastal Seatomisers may have their, typically daytime, power transmitted inland when the economics of community and industrial needs warrant it, or from further offshore where there is an HVDC link.

Atop each mast there are electrically-powered crucibles by which ferric chloride pellets can be sublimated to produce nanoparticulate iron salt aerosols (ISA) designed to catalyse the photo-oxidation of atmospheric methane and other pollutants by means of chlorine radicals. Cleansing hydroxyl radicals may also be generated from the finer droplets.

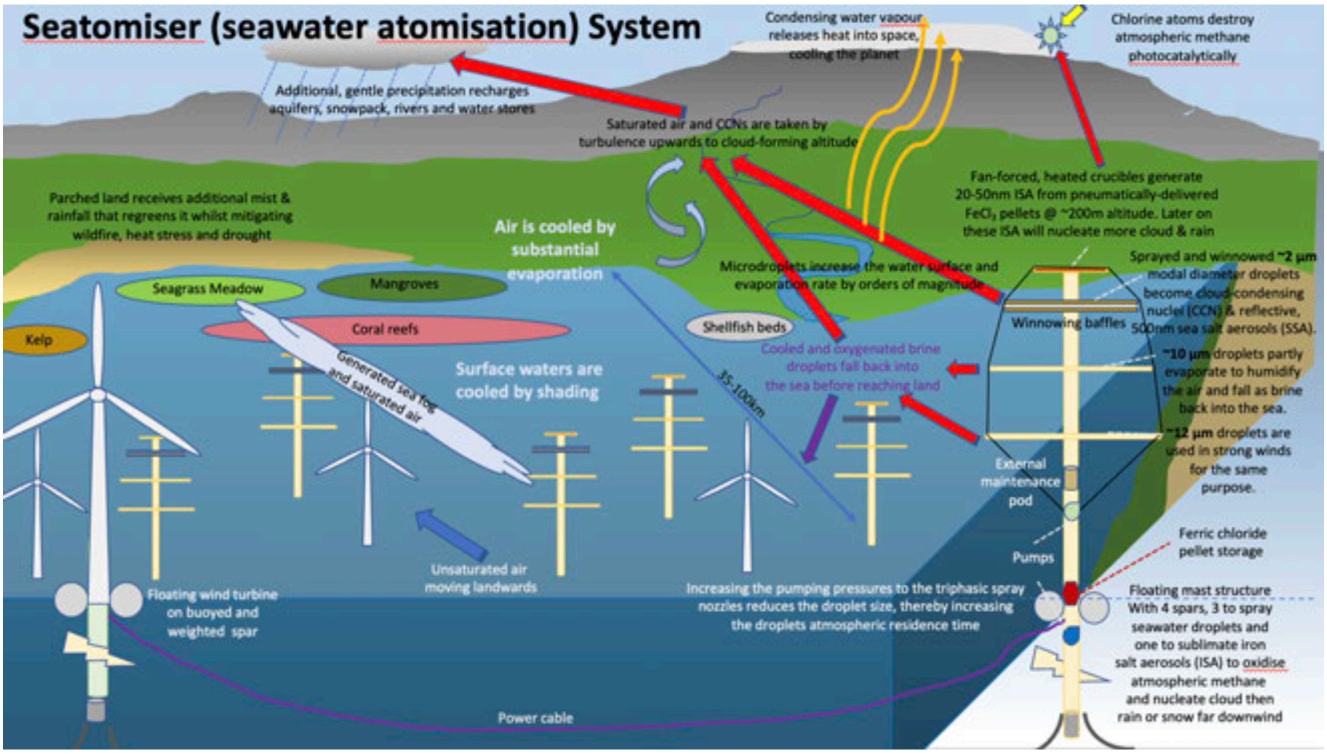
The upper spray assembly sprays finer droplets of a narrower size distribution using customised, higher, possibly triphasic pressures, and flat fan nozzles. The fast-evaporating droplets from these are then winnowed cyclonically by twin baffles to leave desirable, low-micron droplet diameters by to form droplets and crystals for cloud nucleation or sea salt aerosols (SSA) to produce a reflective haze. Both types would tend to stay aloft for days until rained out, whilst reflecting sunlight to cool the air, water, soil, and life forms below or beneath the sea. Their small size makes them capable of being lofted to cloud-making altitude by turbulence, where they may form marine cloud and eventually precipitation far downwind. Should such tiny salt nanocrystals or cloud condensing nuclei (CCN) nucleate precipitation downwind, dilution would cause the resulting raindrops typically to be purer than river water and therefore not harmful should they fall on land. Their size of the nuclei may be changed by changing the pressures at which they are generated. This and downwind weather forecasts can be combined to influence where the precipitation occurs, its form and intensity.

Anchored in deeper waters, arrays of Seatomiser units should be able to have significant regional cooling effects: on the warm ocean surface currents that power extreme weather events; on ocean stratification; on sea ice; and on methane clathrate melting. The main cooling effects are: to increase atmospheric albedo; to increase the rate of evaporation of seawater and the subsequent long wave radiation of its released vapour heat content, on condensation, into space - mainly at night. As the method should typically increase ocean surface evaporation in sunlit seas by orders of magnitude, so would the heat flow released by the condensing precipitation increase off-planet thermal radiation.

Key Functions
Regional downwind cooling through sea fog and marine cloud formation & brightening and SSA reflection; increasing thermal radiation off-planet; protecting coral reefs, seagrass meadows, kelp forests, mangroves and shellfish beds; fishery and aquaculture enhancement; mitigating the effects of extreme weather events such as wildfire, drought, flood, storm damage and hurricane; reducing heat stress; reducing atmospheric methane and smog; oxygenation and cooling of surface waters; afforestation by local species; beneficially influencing gentle dewfall and precipitation downwind, including reclaiming coastal deserts, farmlands and drought-stricken areas by restarting or reinvigorating evapotranspiration and the hydrological cycle, together with increasing water stores, snowpack and aquifers. When not required for spraying or sublimation, the sustainable wind power could be delivered onshore or to visiting vessels and local activities, provided battery or supercapacitor energy storage were installed in the wind turbine towers.

Innovation Dependencies
Successful modification of commercial spray nozzles to operate at much higher pressures and hence producing smaller droplet sizes.
Franz Oeste’s ISA sublimation concept that generates effective, photocatalytic nanoparticles.
Extensive supporting documentation is available at https://www.noac.info/ReferencesDetail.aspx

Graphic



FIZTOPS

Short Description

A Fiztop (a top-shaped producer of fizzy bubbles) is a floating, lightweight, solar-powered unit designed to generate long-lived, reflective nanobubbles in the sea surface microlayer (SSML).

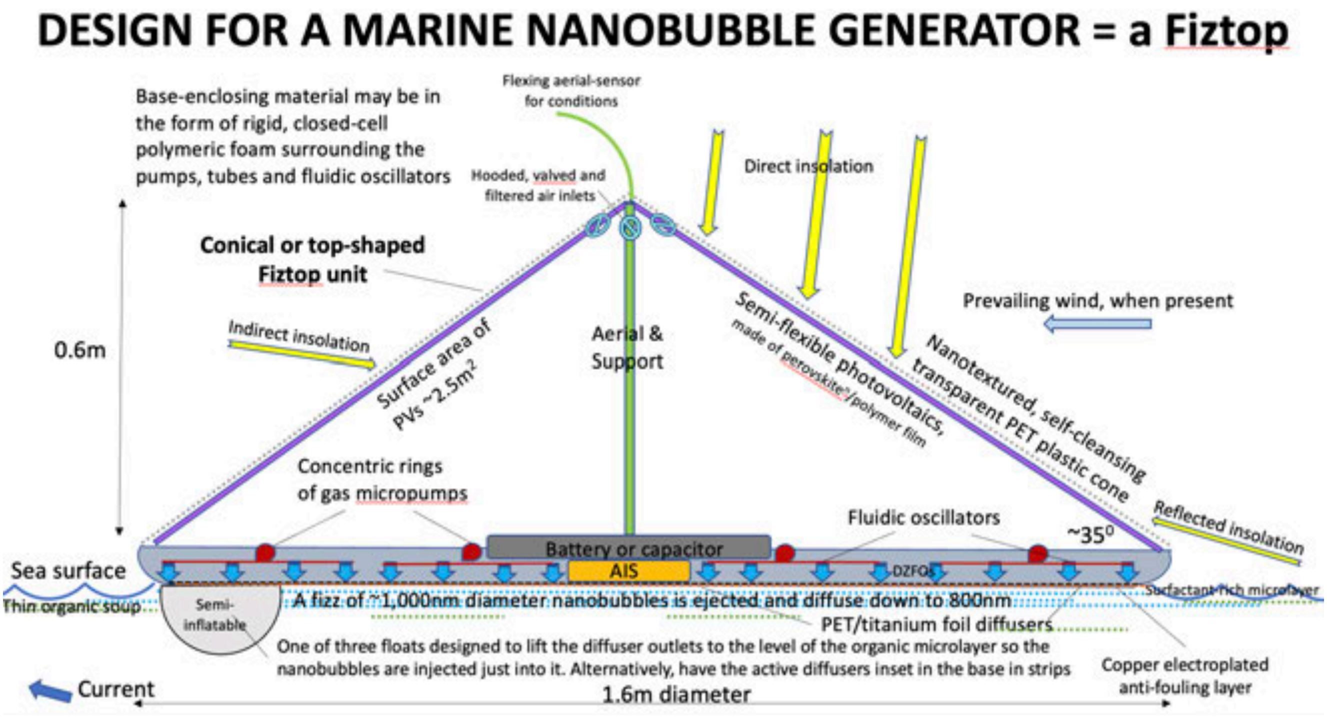
Key Functions

Surface ocean albedo increment to so reflect a portion of sunlight from the ocean surface that the water is cooled, thereby protecting ecologies such as coral reefs, seagrass meadows, kelp forests, mangroves, fish nurseries and shellfish beds from bleaching or overheating, and the water from stratifying and losing some of its oxygen and nutrient content. Increased ocean evaporation as sunlight that would otherwise heat the deeper water is refracted and reflected partly sidewise to warm the surface. Improved and extended atmospheric, shipping and marine sensing.

Innovation Dependencies

Perlemax DZFO technology; Winwick DZFO manufacture and diffuser technology; Flexible photovoltaics, Nanotextured self-cleaning surfaces, Artificial Intelligence System (AIS), comms and sensor technologies; and anti-fouling technology.

Graphic



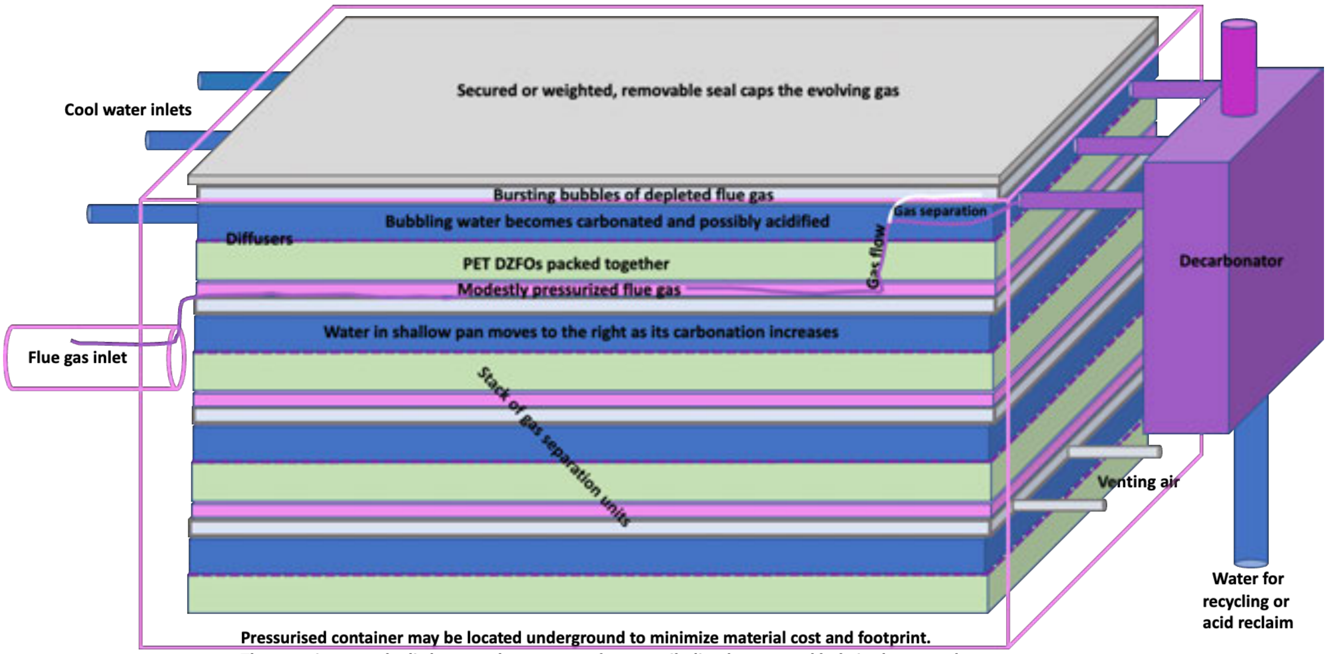
GASGUZZLER
Short Description
Most CO_2 separation technologies depend on expensive chemicals, pollutable matrices, fragile membranes or energy-hungry processes. This conceptual GasGuzzler process uses only recyclable water (which can even be impure or salty water), mild changes in pressure, and modest energy requirements. It may be so designed that it fits into shipping container modules suitable for assembly stacking and transportation. Notionally, it should be both energetically cheaper and more scalable than other, better-known CO_2-separation processes. When deployed with associated infrastructure, it would mean that most large, point sources of CO_2 could be made virtually emissions-free - assuming that there is sufficient industrial requirement for the gas.

Its effectiveness depends on the much greater solubility of CO_2 in water than most other flue gases. After cooling and cycloning to remove particulates, the flue gas passes through a no moving parts Desai Zimmerman Fluidic Oscillator (DZFO) and Winwick diffuser which together generate clouds of monodisperse (same-sized) microbubbles in shallow streams of water in stacked trays. The high surface area of these bubbles means that, under light pressure, they can absorb most of the CO_2 from the flue gas, whilst excluding most of the other gaseous content. Gasified water is continuously removed from the trays and pumped to a low-pressure container that strips off the ~94% pure gas, the residual gas possibly being mainly oxygen. The water is recycled until its acidic content warrants separation. An alternative name for the process is the Soda Pop method.

Key Functions

It could be used economically to separate 94% pure CO_2 from cool or hot, possibly acidic and/or particulate-rich flue gas, or raw natural gas.

Graphics



ICE SHIELDS

Short Description

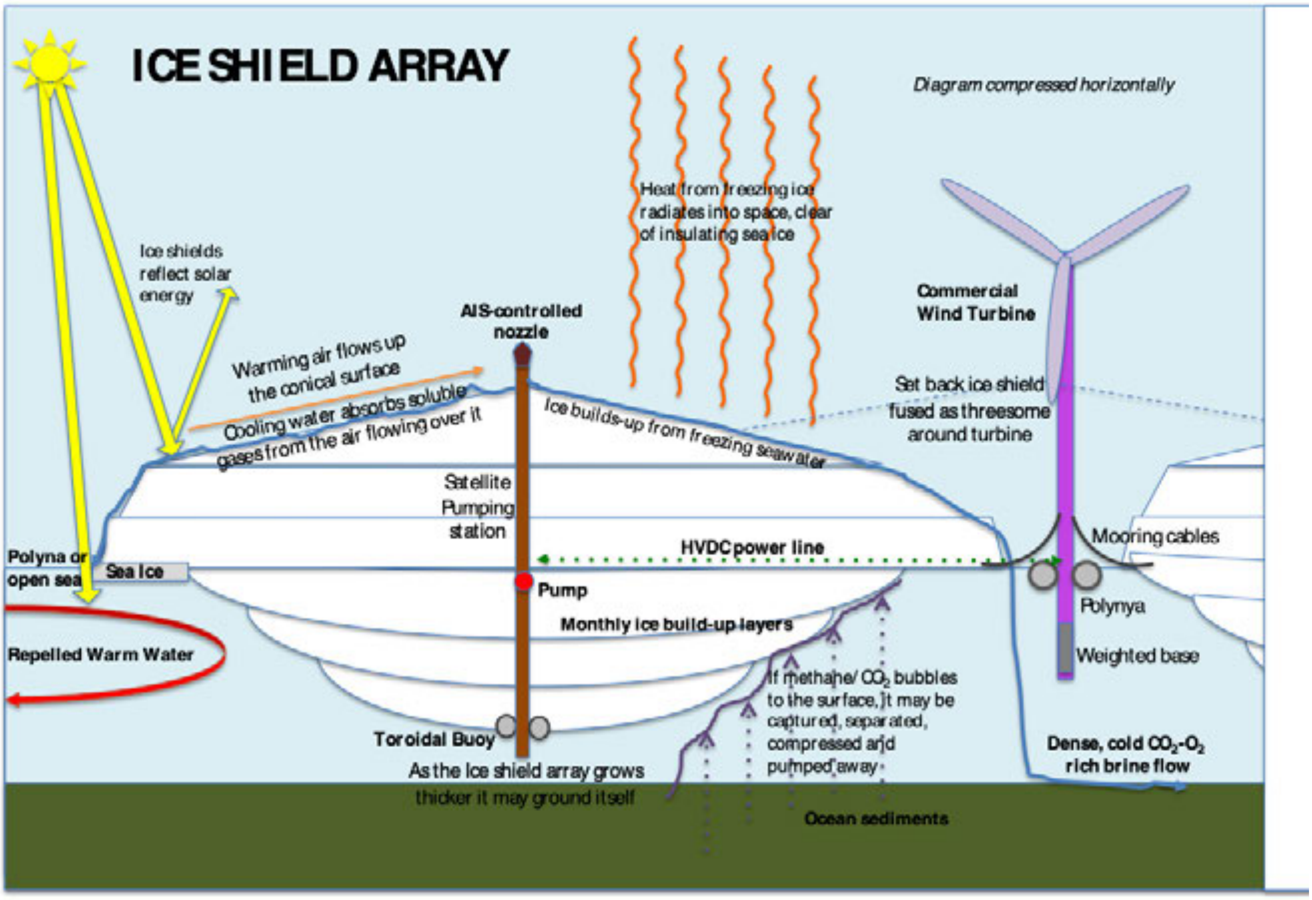
Thickening sea ice can be achieved when anchored, cold-adapted, Arctic wind turbines provide renewable energy to power low-lift, satellite seawater pumps and other system requirements. In the freezing season, AI-controlled pumping stations would optimise intermittent flows of seawater, first onto newly-formed sea ice, then onto each low-angle conical ice shield or lens as it built up – rather like how flowing lava down a slope can form a mountain. A frigid atmosphere and ice surface causes chilling from both above and below. This forms frazil ice crystals in the thinning, radial flow which attach themselves to the chilled ice below. The progressively chilling residual brine concentrates the dissolved carbon dioxide and oxygen in the brine (and may absorb more gas from the atmosphere), together with most of the salt from the seawater. Falling off the edge of each ice shield, the dense, 'brinefall' rivulets would take their contents directly to the seabed, where the CO_2 could react with seabed carbonates to form benign, long-lasting, dissolved bicarbonate, and the oxygenation could succour benthic life. Back of envelope calculation suggests that this method has the potential to sequester up to 16GtC/yr in Arctic abyssal waters alone. Brinefalls on a wide scale would also reinvigorate the overturning currents that keep our oceans productive and the climate and weather in much of the northern hemisphere benign. Ice shield-arrayed polar regions would help return the global climate to its pre-industrial happy state. It is estimated that ice could be thickened at an average rate of around 2cm/h in the freezing season, which is approximately 0.5m/day, or some 80m/yr.

Over its extended, and possibly refurbished, life, a single, 2.5MW floating wind turbine might power the growth of up to 50, ~5km^2 ice shields in a linked array that could be grown and grounded in water up to several hundred metres deep. Designated channels and polynyas amongst the ice arrays would provide access for shipping and habitat for polar wildlife. Deep arrays would repel the intrusion of warm water into the Arctic Ocean, thereby reducing melt loss and glacial calving. Thermals derived from released ocean heat to the atmosphere in the cold and dark seasons would take the heat directly by convection to the tropopause, whence it would radiate into space, unhindered by the insulating greenhouse gases below it, thereby cooling the planet. Increasing ice cover would reverse previous losses, whilst the semi-permanent increase in ice cover would effectively reflect warm season sunlight by its high albedo. Spare, warm season wind power might: be used to generate cooling marine cloud brightening; be taken to market by HVDC cable; be used to capture and process seabed emissions locally into no-drill natural gas, hydrogen, ammonia, nanocarbon products and vat protein; be used to generate iron salt aerosols (ISA) from sublimated ferric chloride pellets that destroy polluting atmospheric methane, nitrous oxide, black carbon, ozone, CFCs and smog by photo-catalysis; or else be used to pump Arctic river water south for use by industry, for irrigation, homes and habitat restoration.

Key Functions
Increasing polar and sub-polar albedo by restoring cryogenic habitat, whilst allowing ship and marine life all-year access to the regions; increasing thermal off-planet radiation; sequestering CO_2 safely and for centuries; reducing glacial loss; cooling the arctic and some sub-arctic regions; restoring benign hemispheric weather by increasing the polar vortices and the Atlantic Meridional Overturning Current (AMOC); preventing coastal erosion; helping to oxygenate the deep ocean; providing renewable energy; and allowing ebullient methane and CO_2 to be harvested before they reach the atmosphere.

Innovation Dependencies
Polar weatherisation of floating wind turbines and pumping stations; AIS capability to so vary the intermittent pumping regimes that linked and often-grounded ice shield arrays can be grown out from the shoreline; development of ebullient ocean gas harvesting, processing and transportation methods.

Graphics



INDUSTRIAL PROCESS IMPROVEMENT

TURQUOISE HYDROGEN

Short Description

Green hydrogen is made from pure water by energy-intensive electrolysis. However, the co-product oxygen will have little value at the volumes required by a hydrogen-based economy. Emissions-free turquoise or blue-green hydrogen is being produced using plasma torch technology to split methane. However, the value of its potential pure carbon co-products from high-temperature variant torches that generate gaseous carbon should allow it to outcompete green hydrogen.

Hydrogen is best stored and transported as piped methane (CH4), compressed natural gas (CNG), or liquefied natural (or bio) gas (LNG), then generated on-demand, on-site - preferably using renewable energy delivered (possibly from far distance) over High Voltage Direct Current (HVDC) powerlines.

Key Functions

Hydrogen has many functions ranging from its many chemical uses, as a reductant for metal ores, in fuel cells, in high temperature uses, and in fermentors.

Innovation Dependencies
None

Graphics
Not relevant

INDUSTRIAL PROCESS IMPROVEMENT

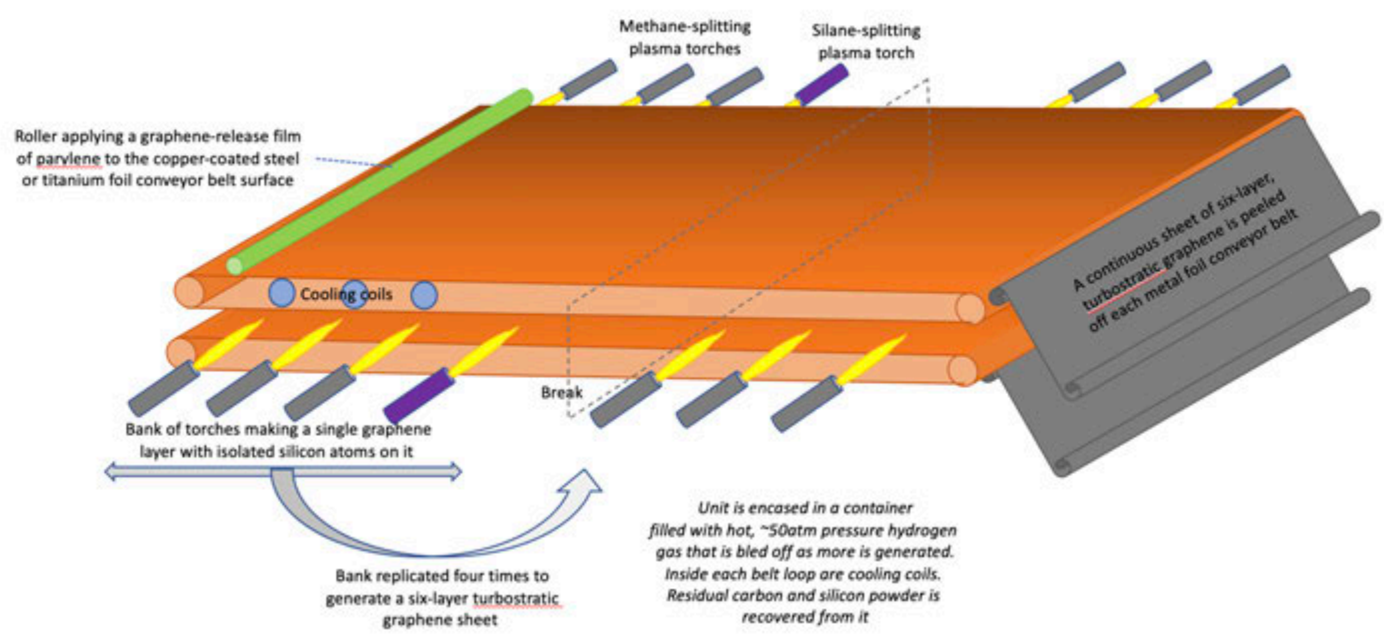
PURE CARBON PRODUCTS
Short Description
Most plasma torch methods produce modestly valuable carbon black as a co-product from methane splitting. However, the torch method used by HiiROC generates gaseous carbon which might be crystallised into much higher value graphene products. Moreover, still higher value might be achieved using Winwick's conceptual Few Layer Turbostratic Graphene (FLTG) film method, which has possibly the highest electrical conductivity of any known material. Ribbons of this might be formed into a high-performance alternative to metal-based powerlines, cabling and wiring. A non-turbostratic, multilayer alternative, when twisted or plaited, could be used to form ultra strong and lightweight cable of any length required and having a tensile strength of 130 GPa. Such could form the basis for a space elevator. Both materials might be formed in the way similar to that indicated below, with the FLTG variant being given its turbostratic nature by silicon atoms derived from silane (SiH_4) interspersing the graphene layers.

Key Functions
Include:
- graphene film/sheet of different numbers of electrically-bonded layers
- ribbon graphene-based cabling, including that for space elevators
- reinforcing fibres, mesh or chaff (possibly in plastics, concrete and matrix materials)
- the conductive part of electrical wiring
- ultra-strong, lightweight and metal-free electricity transmission lines, including HVDC ones
- the conductive element in Winwick super/ultracapacitors
- catalysis
- plasmonics
- construction
- space/solar sails

Innovation Dependencies
HiiROC

Graphics

An Improved Method for Turbostratic Graphene Film Production



WINWICK SUPERCAPACITORS

Short Description

There are ordinary supercapacitors that utilise electrostatic double-layer capacitance (EDLC) and electrochemical pseudocapacitance, but the Winwick variant should add substantially to their capabilities by replacing the relatively thick, typically metal electrode collector/conductance layer with a much thinner layer of Few Layer Turbostratic Graphene (FLTG) that should markedly increase energy density. The electrolyte is an ionic liquid doped with transition-metal oxides and incorporating particulate graphene, whilst the dielectric separator may be made from ultra-thin, recycled PET polymer. The separator may be made porous to conducting ions as required.

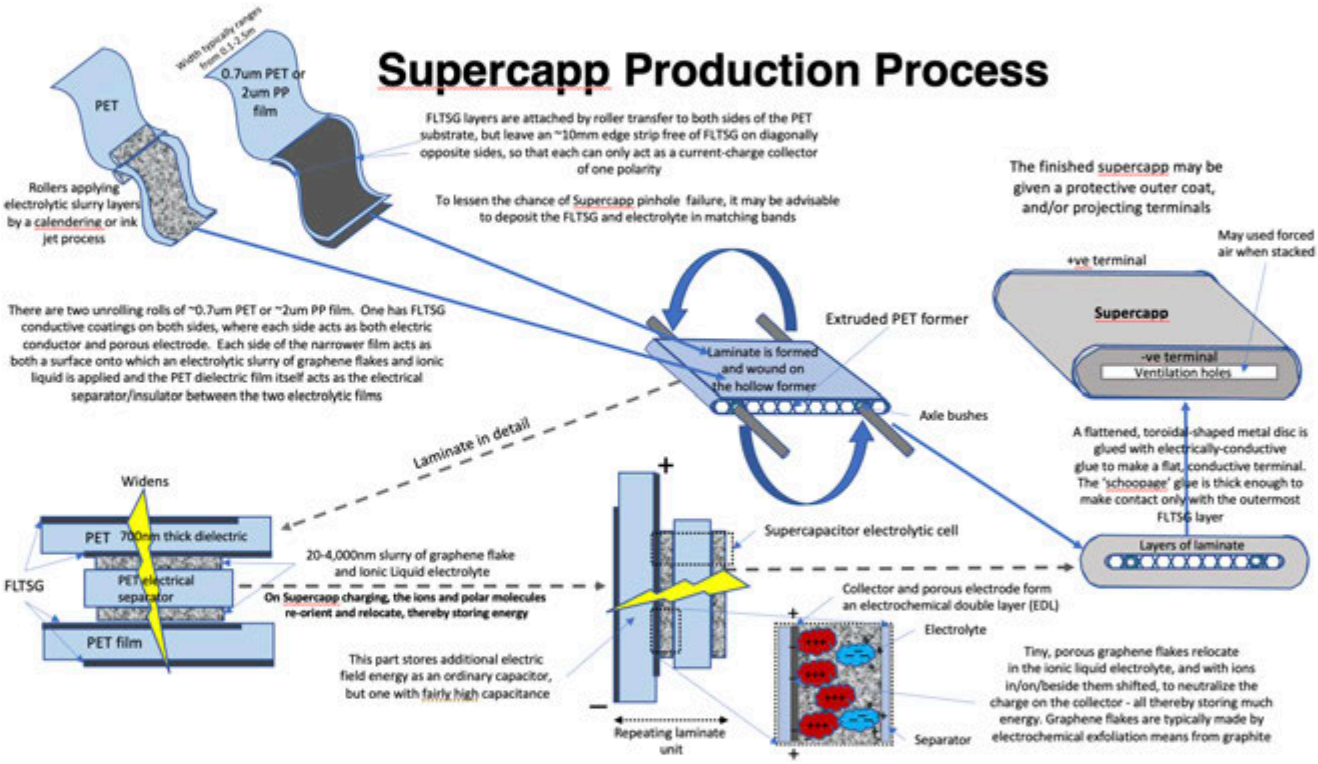
Key Functions

- Replace the large chemical batteries (and their consumption of increasingly scarce metals) in electric vehicles and for other domestic, community, industrial and utility needs.
- Replace large amounts of fossil fuel used in engines, or to generate electricity or heat.
- Decarbonise the shipping, railway, drone, and short haul aircraft industries.
- Electronics

Innovation Dependencies

- HiiROC's plasma torch technology
- Kilowatt Labs' power release software
- Possibly other supercapacitor patents

Graphics



FLUIDIC OSCILLATORS

Short Description

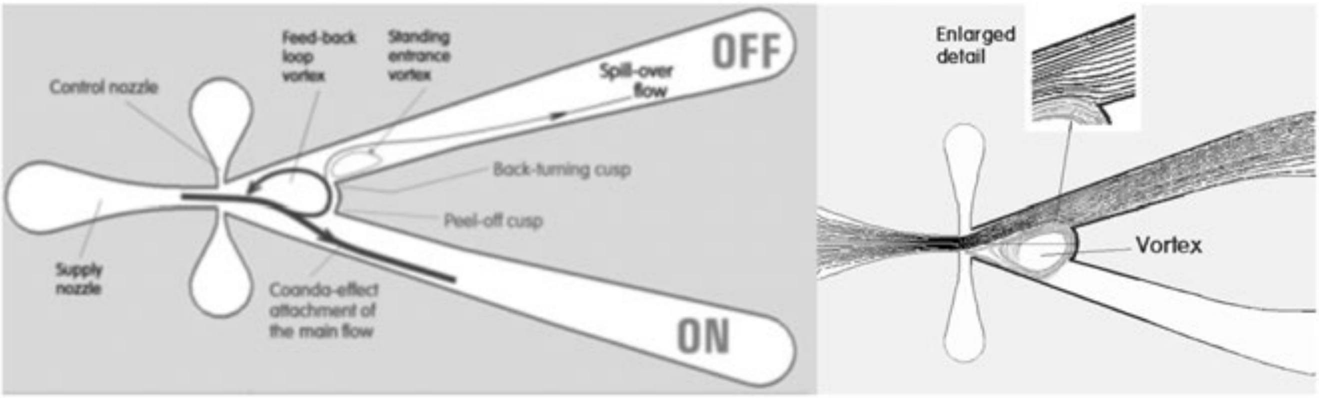
Perlemax's fluidic oscillators are no-moving-parts actuators that split gas moving through a pipe into two, pulsing streams of partly selectable pulse rate by means of changing the pressure. Directed through a diffuser's pores, these pulses can then generate evenly spaced, monodisperse bubbles in a liquid at what is probably the lowest energy cost possible. Such has a multitude of uses. Winwick Business Solutions P/L has designed methods to make banks of such oscillators economically.

Key Functions

- In water and wastewater treatment
- In anaerobic digestion
- In fermentors that can be very large and hence economical
- In Fiztops for ocean brightening
- In Winwick Drillhole Reactors
- In oxygenating water
- In aquaculture
- For sterilisation and disease control
- In GasGuzzlers
- In isothermal distillation
- In algal harvesting and mineral extraction by froth flotation
- In providing CO2 for algaculture

Innovation Dependencies
Perlemax patents and expertise
Winwick diffusers
Winwick WDRs

Graphics



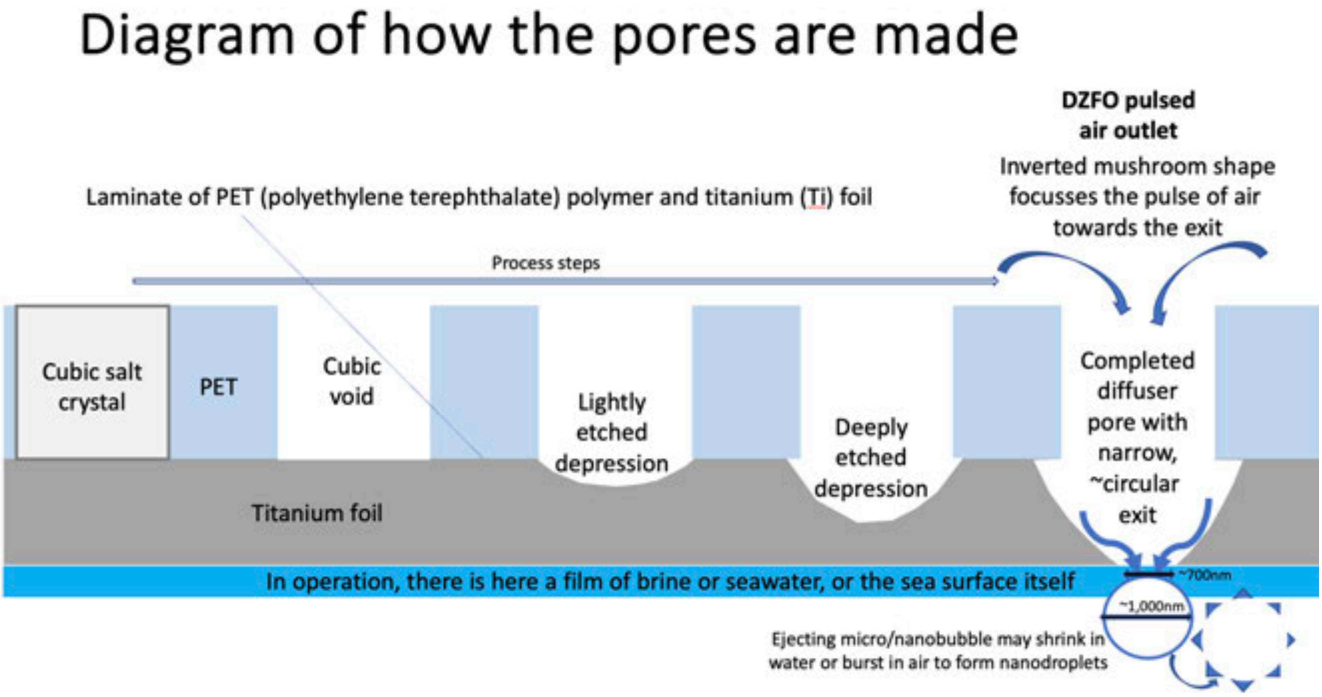
WINWICK DIFFUSERS
Short Description
Typical bubble diffusers are made either from perforated metal sheet or of sintered glass, ceramic or stainless steel beads. Glass ones are typically 1.6mm thick, whilst ss ones to carbonate beer tend to be a few millimetres thick - giving them a pore length (and resistance) that might be half as great again. When monodisperse (same sized) microbubbles are to be produced from many square metres of diffuser, both these methods are suboptimal, for mainly the reason that the bubbles produced are far from monodisperse, but also because of the higher energy cost of passing them through relatively long, twisting pores, of differing average diameter, that fluctuate greatly in cross-sectional area, when compared to straight pores of Winwick diffusers, made from titanium foil with a smear of PET, of which the pores have much less variable cross-section and that are less than 0.3mm long. Sintering using rods of chopped up glass wool does not overcome all these deficiencies. Monodisperse bubbles that are separated by standard but minimal distances are superior because it means: no bubble coalescence and hence a more effective gas and heat exchange can occur; much larger and more efficient fermentors; and nearly simultaneous bubble decavitation under increasing pressure that vastly increases the rate of physicochemical reactions.

Winwick PET/Ti diffusers are designed to be made from commercial titanium foil coated on the inlet side with a thin lamination of PET polymer. The laminating process uses rollers to apply a thin layer of molten polymer to the foil. The polymer contains tiny, monodisperse crystals of table salt, generated by adding an alcohol to a turbulent solution of saltwater so that crystals form in it and are filtered off when the right size has been reached. The right size is that when the cubic crystals reach what is to be slightly more than the thickness of the PET laminate. Thus, during the lamination process the crystals touch both the foil and the air, probably slightly fracturing the crystal. After the lamination process the thin diffuser sheet is washed in water to remove the salt, dried, and a porous roller applies aqua regia (a 3:1 mix of concentrated HCl and HNO3 acids) to the polymer side in order to etch tiny, randomly distributed holes, each of nearly the same size in the foil. Once the etching process has proceeded far enough, the diffuser sheet is washed and dried before being attached to a suitable support framework at the 'foot' end of the fluidic oscillator. A diffuser roll may previously have been tested and treated to plug any coalesced pores.

Key Functions

- Cheaper, faster and larger scale precision fermentation
- Simultaneous bubble decavitation that improves yield
- Better gas to liquid and heat transfer rates
- Lower energy costs
- Increased process control
- Utilises the amazing energetics of bubble decavitation

Graphics



LASER SPALLING & DRILLLING

Short Description

Winwick Drillhole Reactor (WDR) physicochemical will depend on our ability to drill fairly wide holes (>60cm) vertically deep (>3km) into the ground. Whilst geothermal drilling techniques can do this, they are expensive and take months to drill using standard drill bits. Interesting experiments have been performed using lasers to spall rock that has been wetted so that it spalls off when hit with a strong laser beam. A fast and economical drilling method should be possible whereby a rotating cylinder of lasers spalls almost the whole rock face at once and the spalls are removed up the drillhole by powerful pneumatics through a flexible central pipe. The drilling head might be supported by three cables so that the head could be steered through low angles. The unit would spall a hole wider than the cylinder's diameter and might even be made to work through an aquifer using water as the spall-carrying fluid. Now, a 66cm geothermal drill bit has been run at a penetration speed of

10m/hr for ~100m, see https://petrowiki.spe.org/Geothermal_drilling_and_completion . However, deeper and/or hotter holes would require drill bit exchanges that would reduce this substantially. Laser spalling using this variant might need no such exchanges and might drill even faster.

Key Functions
- Faster and more economical drilling
- Less chance of stuck drill bits
- Better operation at high temperatures

Graphics
TBD

WINWICK DRILLHOLE REACTORS
Short Description
A WDR is basically a deep pipe within a pipe, with the inner pipe being a little less deep, thereby allowing a descending slurry to move into an annular ascending tube. The slurry may also contain inert densifiers, such as drilling mud or finely divided oxides, to increase its density and heterogenous, powdered catalysts. A key part of the WDR is its employment of monodisperse microbubbles, being injected by Perlemax fluidic oscillators, lances and diffusers into the slurry as it begins its pumped descent. These bubbles first heat up as a result of adiabatic compression under increasing gravitational pressure. Then, at a given distance and pressure below, they all decavitate, virtually at once. This gives rise to three energetic effects: micro pressure waves, micro (perhaps piercing) jets, and an instantaneous temperature spike around each bubble decavitation of some 5,000^{0}C - which is sufficient to make many chemical reactions to occur, yet may not allow sufficient time for the establishment of equilibrium conditions and hence for the forward equilibrium reactions to reverse, hence probably increasing product yield substantially. Exothermic reactions would increase the slurry temperature, endothermic ones reduce it. Should high, bulk temperature be required, this can either be added either by heating the input materials or else by heating the drillhole casing, probably electrically, or else by utilising rock heat at depth. On the upwards passage, gas may come out of solution and expand, thereby cooling the product slurry. The WDR, which will typically be a few kilometres long, acts as an efficient, counter-current heat exchange. Centrifuging and bleed-off may be used at the wellhead to separate slurry constituents and products. The non-product components of the slurry would then typically be recycled after new, raw materials had been added.

Key Functions
- Ammonia synthesis
- Depolymerisation of biomass and plastics (hydrothermal depolymerisation or liquefaction)
- Hydrothermal carbonisation of moist biomass, seaweed or bark into biochar
- Cell rupture (especially of phytoplankton, seaweed and foliage)
- Fibre Release
- Esterification
- Oil fractionation
- Syngas synthesis from biomass
- Dimethyl Ether (DME) synthesis
- Methanol synthesis

- Dimethyl carbonate (DMC) synthesis
- Nitric acid synthesis
- Fischer-Tropsch alkane synthesis
- Sub/supercritical water conversion of biomass
- Ore refining

Graphics

see https://patentimages.storage.googleapis.com/0b/9f/99/4f715f8f8aac52/US8715980.pdf

WINWICK AMMONIA SYNTHESIS (WAS)

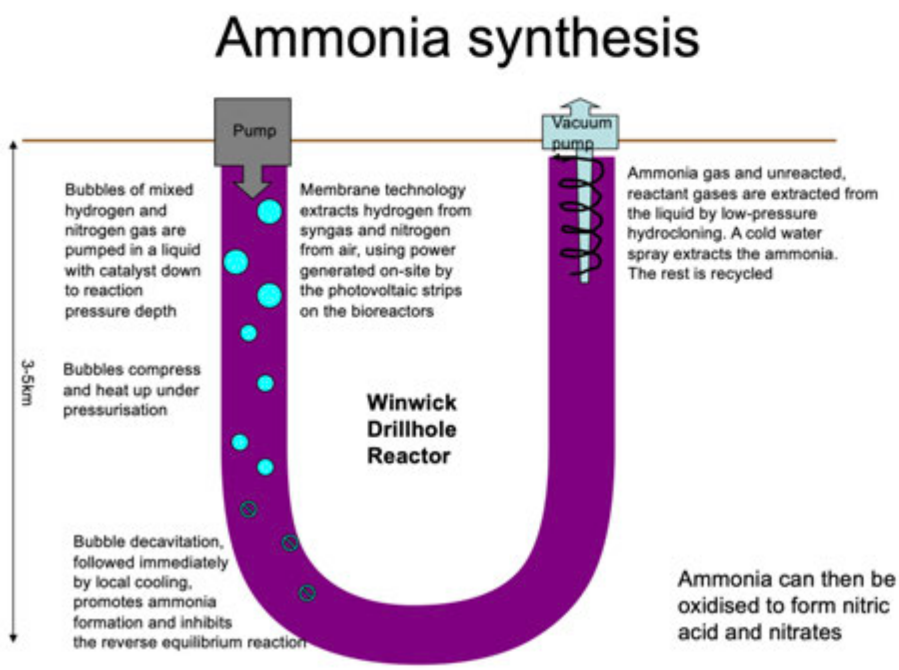
Short Description

The traditional Haber-Bosch process for making ammonia is inefficient, giving only a 15% yield at each energy-intensive cycle. It also consumes some 1.5% of our energy use, most of which is in the form of polluting fossil fuels. Using a WDR and decavitating, monodisperse bubbles of a 3:1 mixture of turquoise hydrogen and nitrogen in water to make it might well reduce the energy use by half and cause much less pollution. The exothermic Haber process uses temperatures from 300-550^{0}C and pressures from 150-250atm. More productive, higher pressures are readily obtained using a WDR, whilst keeping the slurry liquid, below the critical temperature of water, 374^{0}C. The bulk temperature of the slurry might be kept considerably lower because of the instantaneous, high temperature spikes. The catalyst might remain as a finely-divided form of osmium or treated and doped magnetite.

Key Functions

- nearly pollution-free ammonia generation

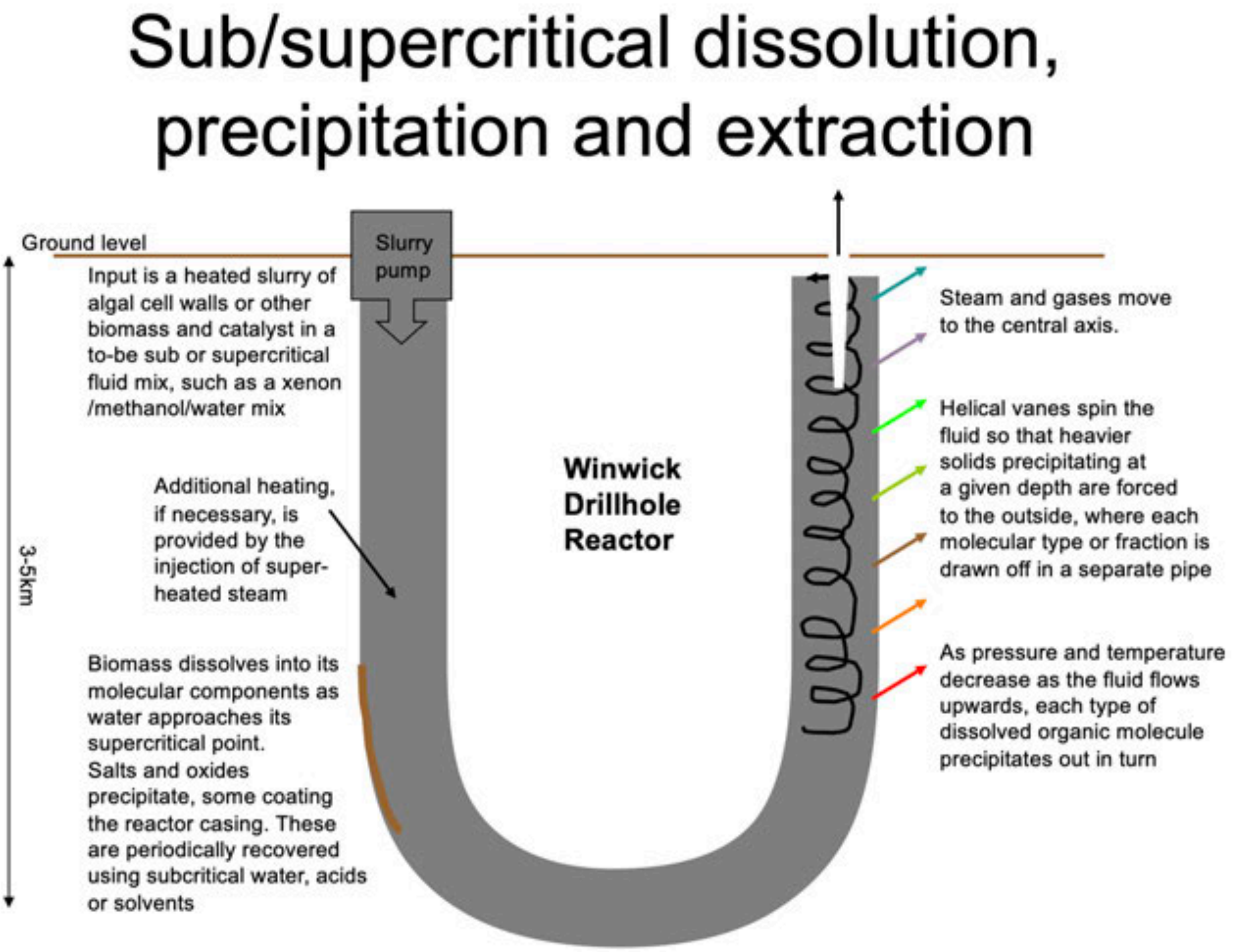
Graphics (simplified)



DEPOLYMERISATION OF BIOMASS AND PLASTICS (by Winwick Hydrothermal Liquefaction, WHL)
Short Description
Water near its supercritical point can probably be 'tuned' by pressure and temperature so that it depolymerises polymers into their constituent monomers. In the case of cellulosic ones, this means into sugars and lignin; plastics into its various monomers; seaweed into sugars, phenols and lipids; chitin into glucosamine; and protein into amino acids. Sugars can be used in precision fermentation; lignin can be made into adhesives, phenolics and carbon products; whilst mixed plastic monomers might be separated then reconstituted into virgin plastics - notionally endlessly.

Key Functions
- Conversion of crop & forestry waste and seaweed into valuable monomers, foods & phenolics
- Endless recycling of plastics, possibly even mixed ones - a major contribution to a circular economy
- Invasive, weed, noxious or feral species may be transformed into valuable products
- Sewage sludge and organic/plastic medical waste may be decontaminated and converted into valuable minerals and simple organics

Graphics (simplified)



WINWICK HYDROTHERMAL CARBONISATION (WHC)

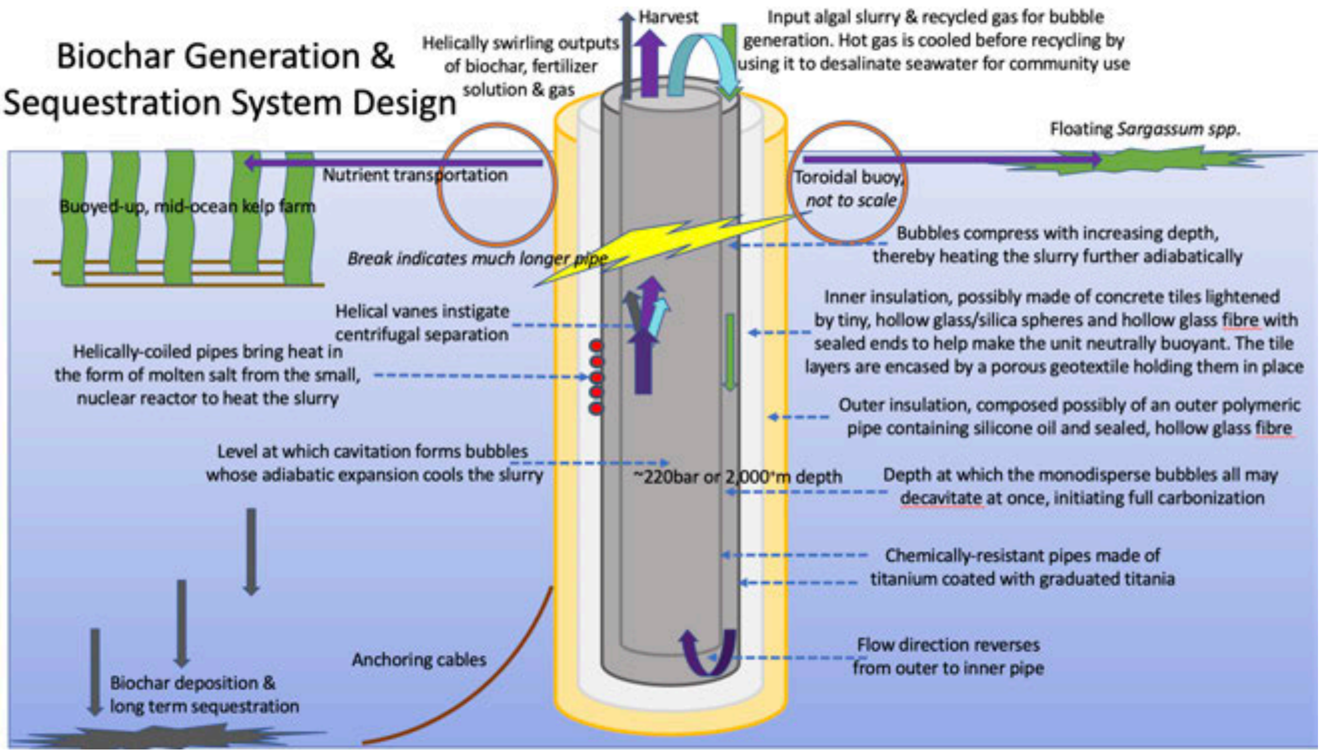
Short Description

At harsher conditions than that for hydrothermal liquefaction in a WDR, dust-contaminated bark, seaweed or moist biomass may be carbonised - if useful then at sea.

Key Functions

- Economical, regional biochar production and wildfire reduction - possibly in-forest
- Opportunity to use the method to control *Sargassum* pollution of coastlines whilst providing fertiliser for desirable species and gaining revenue from enduring carbon sequestration on the ocean floor.

Graphics



WINWICK CELL RUPTURE (WCR)

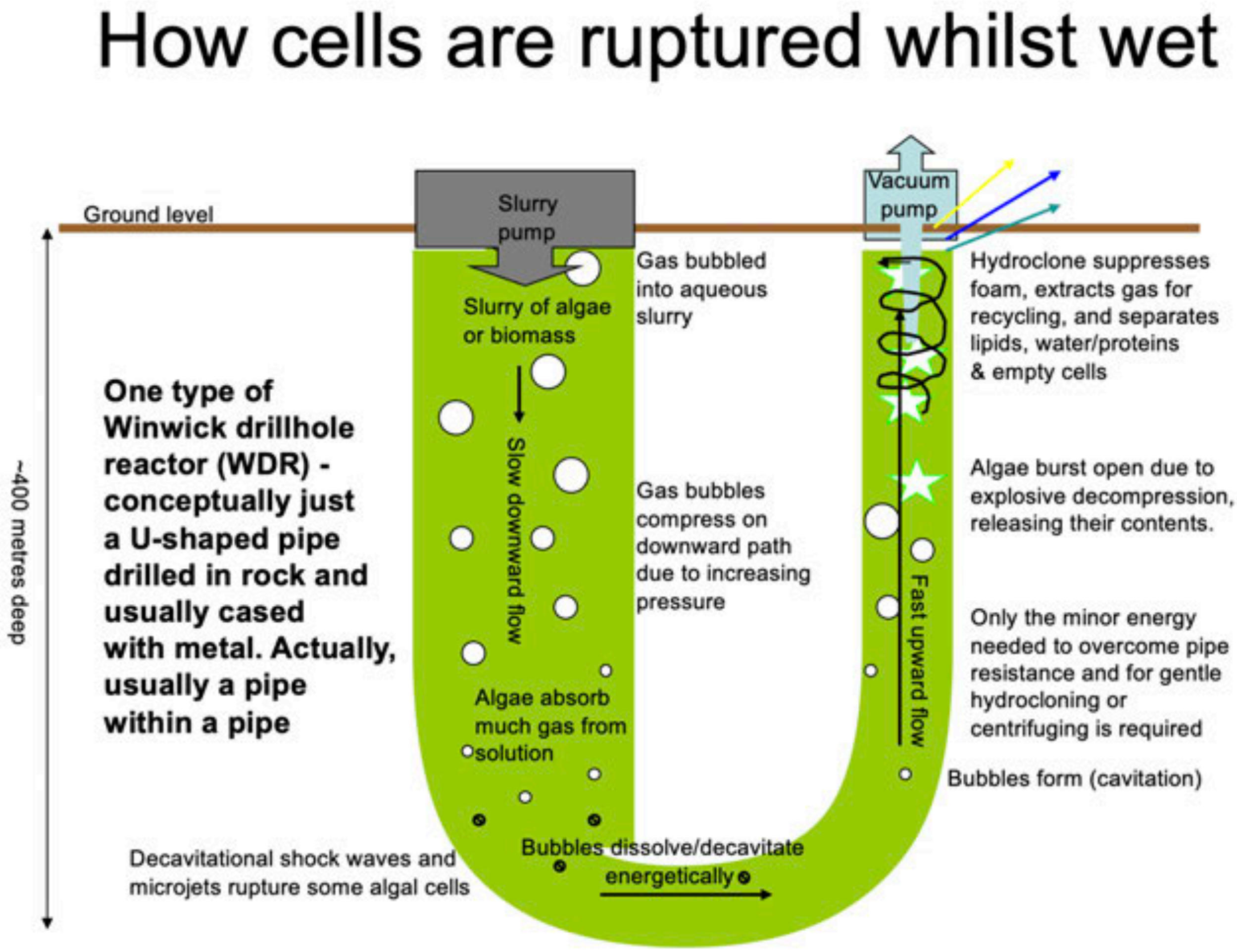
Short Description

Tiny, tough and slippery phytoplankton cells are notoriously difficult to lyse or rupture in order to gain access to their valuable, but often fragile cell contents. Such cells and their internal vesicles can probably be ruptured by explosive decompression from the inside by infusing them under high pressure with a soluble gas, such as carbon dioxide or xenon, then rapidly depressurising them in the upwards passage of a WDR. Moreover, as bubbles tend to attach themselves to solid surfaces, such as those of phytoplankton, the compressing bubbles would decavitate, thereby allowing the microjets generated possibly to blast holes in the phytoplankton cell wall, thereby releasing the lipids, biooactives, gums, vitamins, and the semisolid glycoproteins & polysaccharides of the cell wall. The increasing acidity of the dissolved CO2 might also assist in cell rupture. To increase the effect, a series of constrictions might be place in the upwards passage so the cells were exposed to a series of rapid expansions and contractions. The gas or a mixture of gases would initially be infused by the dissolution, under increasing pressure, of monodisperse bubbles.

Key Functions

- Cellular and vesicle rupture of tough cell walls
- Release of valuable, largely-undamaged organics for harvesting and separation
- The process might be applied to *Sargassum* before the residuum is carbonised.

Graphics (simplified)



WINWICK FIBRE RELEASE

Short Description

Many agricultural wastes and products, including bagasse, sugarcane leaves, grasses, bamboo, rushes, hemp vines, flax plants, jute, kenaf, and agave have valuable fibres. Often these are extracted by time and labour intensive methods, or with harsh chemicals and heat - as with wood chips for paper making. Using acetaldehyde with the low boiling point of 20^0C combined with CO2 or (much more expensive) xenon gas bubbles, or using the alcohol solvents used in the Organosolv process, and a tuned WDR process, may allow the cellulosic fibres to be released faster and more economically.

Key Functions

- Economical release of cellulose fibre from a wide variety of plant materials, including those with sugar, lipid or lignin components

Graphics

None available

ORE LEACHING & REFINING

Short Description

The standard method by which nickel, cobalt and possibly other transition metals are refined from lateritic ore is by high pressure acid leaching (HPAL) using a batch process. This suffers from having high energy costs, high equipment, labour and maintenance costs, and high downtime associated with it being a batch process involving high corrosivity, clogging and wear. Using a WDR variant, these deficiencies might be avoided. Gangue processing and disposal hazard might also be improved by the means illustrated below.

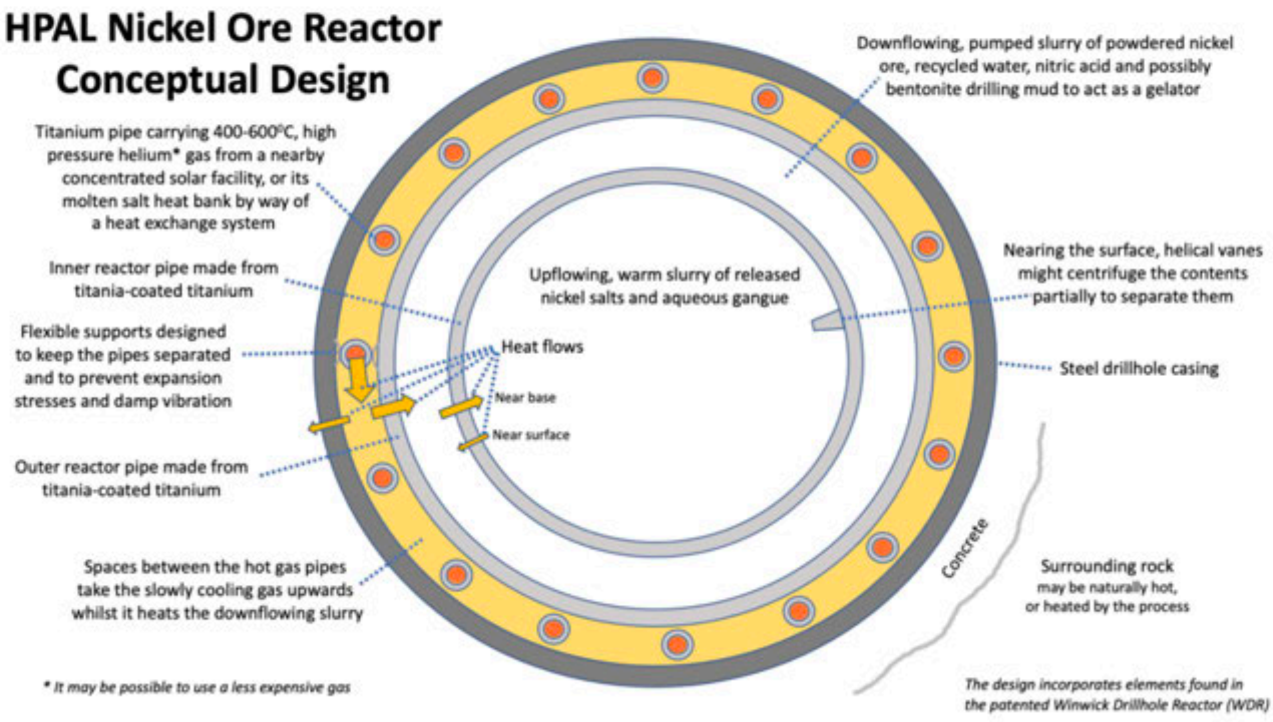
Key Functions

- Improving mineral processing efficiency, whilst reducing hazardous waste.
- Reclaiming and recycling processing acid.

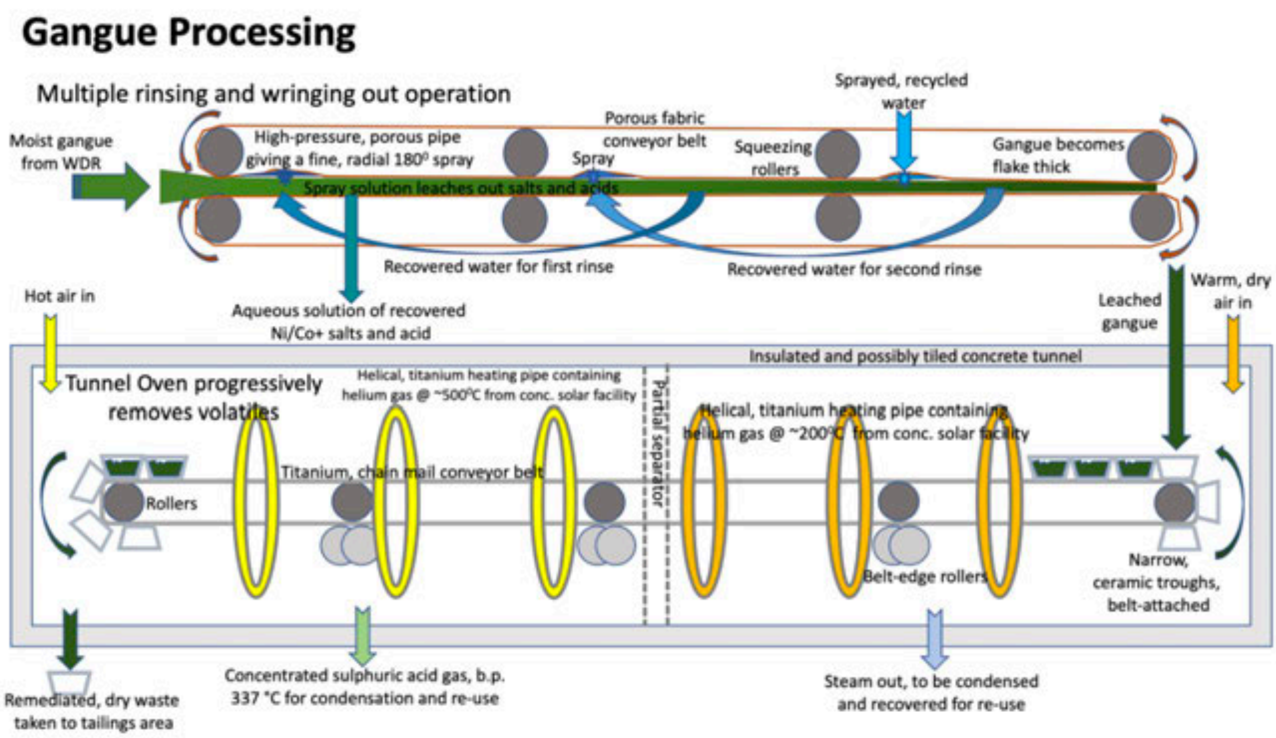
Innovation Dependencies

WDR technology; solar thermal storage; Algal dewatering technology using porous conveyor belts; and Perlemax’ isothermal distillation method for concentrating acidic solutions so they can be recycled or sold.

Graphics



HPAL Nickel Ore Reactor Conceptual Design
Titanium pipe carrying 400-600°C, high pressure helium* gas from a nearby concentrated solar facility, or its molten salt heat bank by way of a heat exchange system
Inner reactor pipe made from titania-coated titanium
Flexible supports designed to keep the pipes separated and to prevent expansion stresses and damp vibration
Outer reactor pipe made from titania-coated titanium
Spaces between the hot gas pipes take the slowly cooling gas upwards whilst it heats the downflowing slurry
* It may be possible to use a less expensive gas
Downflowing, pumped slurry of powdered nickel ore, recycled water, nitric acid and possibly bentonite drilling mud to act as a gelator
Upflowing, warm slurry of released nickel salts and aqueous gangue
Heat flows
Near base
Near surface
Nearing the surface, helical vanes might centrifuge the contents partially to separate them
Steel drillhole casing
Concrete
Surrounding rock may be naturally hot, or heated by the process
The design incorporates elements found in the patented Winwick Drillhole Reactor (WDR)



Gangue Processing
Multiple rinsing and wringing out operation
Moist gangue from WDR
High-pressure, porous pipe giving a fine, radial 180° spray
Porous fabric conveyor belt
Spray
Squeezing rollers
Sprayed, recycled water
Gangue becomes flake thick
Spray solution leaches out salts and acids
Recovered water for first rinse
Recovered water for second rinse
Hot air in
Aqueous solution of recovered Ni/Co+ salts and acid
Leached gangue
Warm, dry air in
Insulated and possibly tiled concrete tunnel
Tunnel Oven progressively removes volatiles
Helical, titanium heating pipe containing helium gas @ ~500°C from conc. solar facility
Partial separator
Helical, titanium heating pipe containing helium gas @ ~200°C from conc. solar facility
Titanium, chain mail conveyor belt
Rollers
Belt-edge rollers
Narrow, ceramic troughs, belt-attached
Remediated, dry waste taken to tailings area
Concentrated sulphuric acid gas, b.p. 337 °C for condensation and re-use
Steam out, to be condensed and recovered for re-use

WINWICK PHOTOBIOREACTORS (PBR)

Short Description

A low-cost, efficient bioreactor for growing phytoplankton on marginal land, making good use of local resources, including sunlight and whatever water and nutrient sources are available.

Key Functions

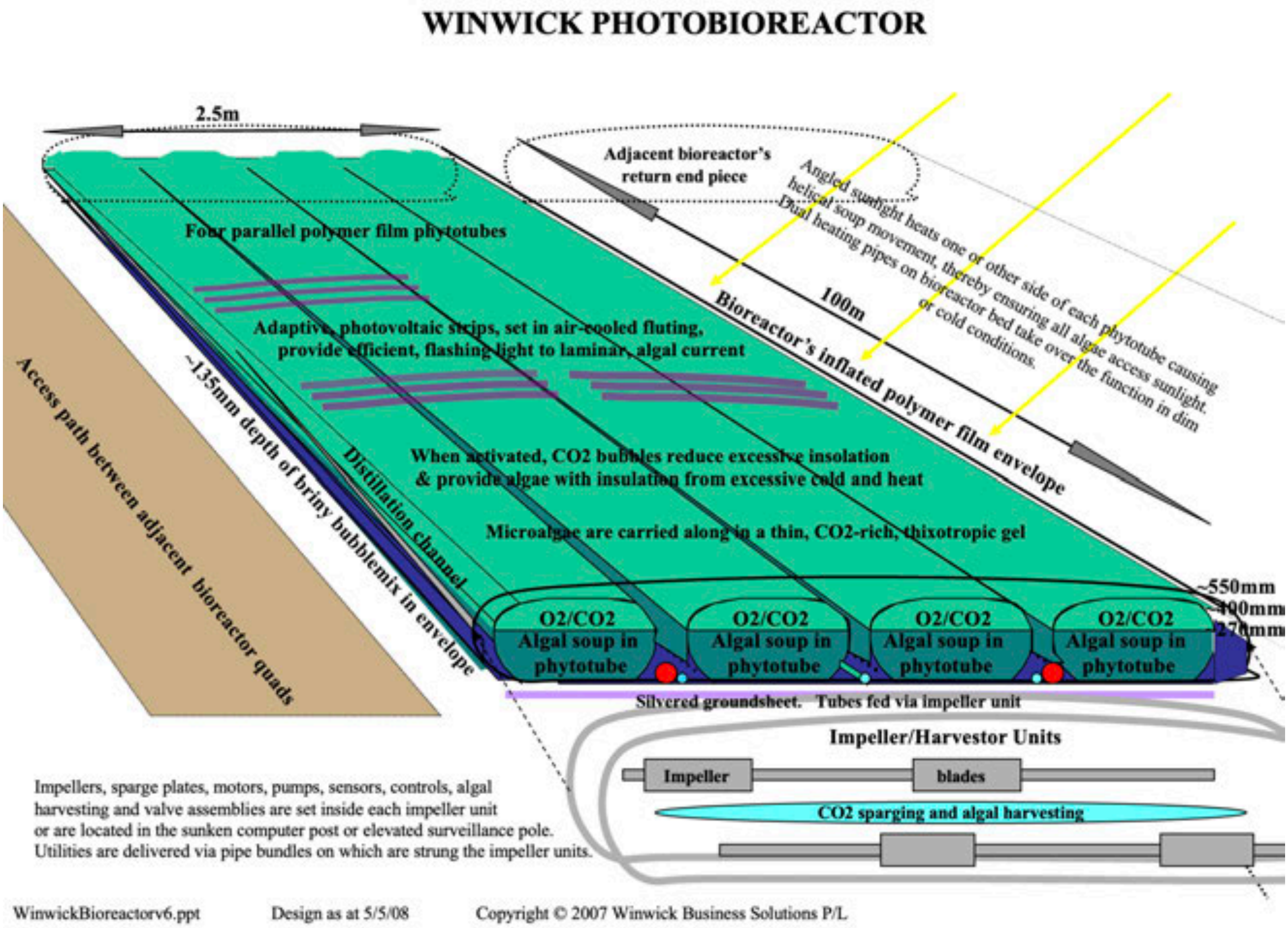
- Generating food, fuel, power and potable water from desert or degraded land.
- Could make remote settlements nearly self-sufficient, as well as potentially profitable.
- Operates best if carbon dioxide and treated wastewater collected from point sources or townships can be piped to the site.
- Should be able to handle weather extremes better than does agriculture.

Innovation Dependencies

Perlemax + Winwick; requires a source of CO_2 better than that of the air. Ideally, would be matched with WDR facilities.

Graphics

See patent https://ipsearch.ipaustralia.gov.au/patents/2011200090 and



Attachment A

SOME CLIMATE CHANGE SOLUTIONS

BUOYANT FLAKES

Short Description

Previous attempts to farm the sea or to increase oceanic carbon sequestration have used soluble, artificial chemicals that do not remain near the surface. However, long-lived, ultra-slow-release buoyant flakes can be disseminated annually by ship over selected ocean areas. The tiny flakes are comprised of natural, organic materials and mineral wastes. Like a self-feed system, these do not so much release the nutrients to the environment, as to make them available at the sea surface where the phytoplankton which need them can 'suck' them out of the seawater, or the exposed mineral particles in the flakes, using their transporter enzymes, or ligands. Thus, there is little chance of either over-fertilisation, eutrophication, toxicity, or of the nutrients being lost rapidly to the dark depths. For iron-rich nutrient, being at the surface allows UV light temporarily to transform/reduce the less-soluble ferric form into the more soluble ferrous form, thereby aiding its metabolisation into phytoplankton biomass.

The foundation of each flake is a single rice husk, rich in the opaline silica needed by diatoms. Glued to this by plant-derived lignin hot-melt glue is a sealed matrix of gas and minerals designed to provide phytoplankton communities with whatever nutrients are wanting in that part of the ocean. As dark blue ocean waters are deficient in one or more macronutrients or trace elements (typically phosphate, iron, silica and transition metals - reactive nitrogen nutrient being able to be made from air by diazotrophs), using buoyant flakes could turn these blue or 'desert' ocean regions into productive, turquoise seas. Substantial sources of already finely-divided and stored nutrients are the red mud residual to alumina refining and the phosphatic clay wastes residual to phosphate extraction. Atomised, rice water glue with dissolved urea leavening agent is used to adhere the mix of lignin powder and minerals robustly to the husks, followed by baking to melt the lignin and gasify the matrix, thereby forming durable, buoyant pellets. These are to be delivered pneumatically from bulk ships to oligotrophic ocean surfaces, typically annually.

Krill and most other diel vertically migrating (DVM) species consume phytoplankton in surface waters at night, then respire and excrete the carbonaceous wastes in the dark, safer (from visual predators) depths of up to a kilometre during daylight hours, thereby sequestering its carbon content.

The nutrient mix can also be adapted to suit methanotrophs (methane eaters) present in water or soil, such as are found in melting permafrost, seabeds, oceans, lakes, swamps, rice paddies, termite mounds, landfills, fracking & mining operations, abandoned mines & gasoil wells, and feedlots.

Key Functions

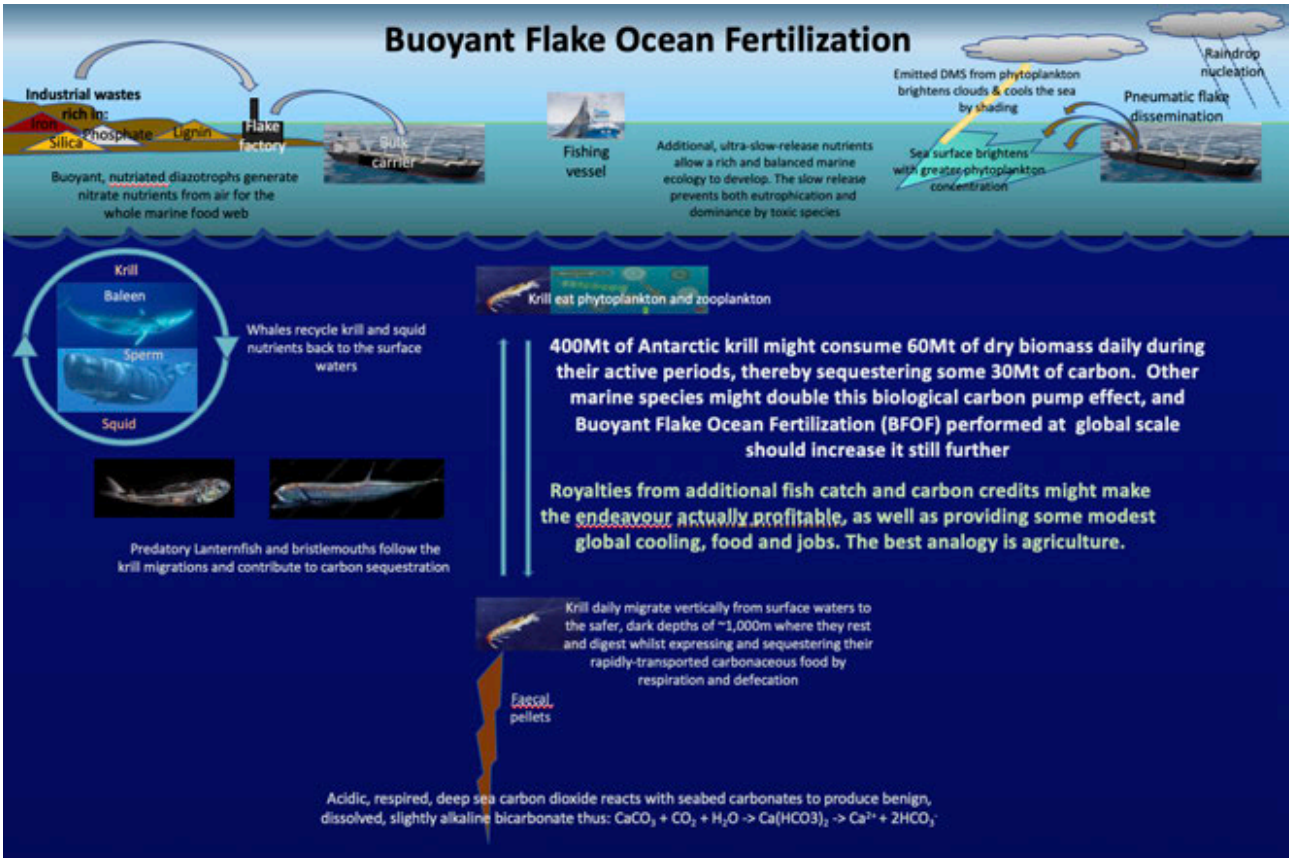
Increases oceanic albedo; increases the biomass and biodiversity of aquatic life; sequesters atmospheric carbon dioxide (CO_2) securely as carbonaceous seabed ooze & rock, refractory dissolved organic carbon (DOC), and benign, dissolved, alkaline bicarbonate; increases oceanic albedo (reflectiveness) that cools the surface waters; increases atmospheric DMS aerosols that nucleate or brighten cooling marine clouds.

Innovation Dependencies

None known.

Extensive supporting documentation is available at https://www.noac.info/ReferencesDetail.aspx

Graphic



SEATOMISERS/ISA

Short Description

Anchored, offshore wind turbines could be used to power satellite, mast-like units that spray filtered seawater of different particle size ranges from three spars into the lower atmosphere. The spray nozzle assemblies on the lower two spars are designed to spray humidifying droplets that partially evaporate to form cooler, moisture-saturated air and brine droplets that fall back into the sea before they reach land. These should be able to help make new cloud where none currently exist, as well as to thicken existing marine cloud. The nozzles on the lowest spar, which produce the largest microdroplets, would typically be activated only in high winds when the power supply is plentiful. Changing the nozzle pressures could be used to determine the modal size of droplets produced and how far they would carry downwind under forecast weather conditions.

Coastal Seatomisers may have their, typically daytime, power transmitted inland when the economics of community and industrial needs warrant it, or from further offshore where there is an HVDC link.

Atop each mast there are electrically-powered crucibles by which ferric chloride pellets can be sublimated to produce nanoparticulate iron salt aerosols (ISA) designed to catalyse the photo-oxidation of atmospheric methane and other pollutants by means of chlorine radicals. Cleansing hydroxyl radicals may also be generated from the finer droplets.

The upper spray assembly sprays finer droplets of a narrower size distribution using customised, higher, possibly triphasic pressures, and flat fan nozzles. The fast-evaporating droplets from these are then winnowed cyclonically by twin baffles to leave desirable, low-micron droplet diameters by to form droplets and crystals for cloud nucleation or sea salt aerosols (SSA) to produce a reflective haze. Both types would tend to stay aloft for days until rained out, whilst reflecting sunlight to cool the air, water, soil, and life forms below or beneath the sea. Their small size makes them capable of being lofted to cloud-making altitude by turbulence, where they may form marine cloud and eventually precipitation far downwind. Should such tiny salt nanocrystals or cloud condensing nuclei (CCN) nucleate precipitation downwind, dilution would cause the resulting raindrops typically to be purer than river water and therefore not harmful should they fall on land. Their size of the nuclei may be changed by changing the pressures at which they are generated. This and downwind weather forecasts can be combined to influence where the precipitation occurs, its form and intensity.

Anchored in deeper waters, arrays of Seatomiser units should be able to have significant regional cooling effects: on the warm ocean surface currents that power extreme weather events; on ocean stratification; on sea ice; and on methane clathrate melting. The main cooling effects are: to increase atmospheric albedo; to increase the rate of evaporation of seawater and the subsequent long wave radiation of its released vapour heat content, on condensation, into space - mainly at night. As the method should typically increase ocean surface evaporation in sunlit seas by orders of magnitude, so would the heat flow released by the condensing precipitation increase off-planet thermal radiation.

Key Functions

Regional downwind cooling through sea fog and marine cloud formation & brightening and SSA reflection; increasing thermal radiation off-planet; protecting coral reefs, seagrass meadows, kelp forests, mangroves and shellfish beds; fishery and aquaculture enhancement; mitigating the effects of extreme weather events such as wildfire, drought, flood, storm damage and hurricane; reducing heat stress; reducing atmospheric methane and smog; oxygenation and cooling of surface waters; afforestation by local species; beneficially influencing gentle dewfall and precipitation downwind, including reclaiming coastal deserts, farmlands and drought-stricken areas by restarting or reinvigorating evapotranspiration and the hydrological cycle, together with increasing water stores, snowpack and aquifers. When not required for spraying or sublimation, the sustainable wind power could be delivered onshore or to visiting vessels and local activities, provided battery or supercapacitor energy storage were installed in the wind turbine towers.

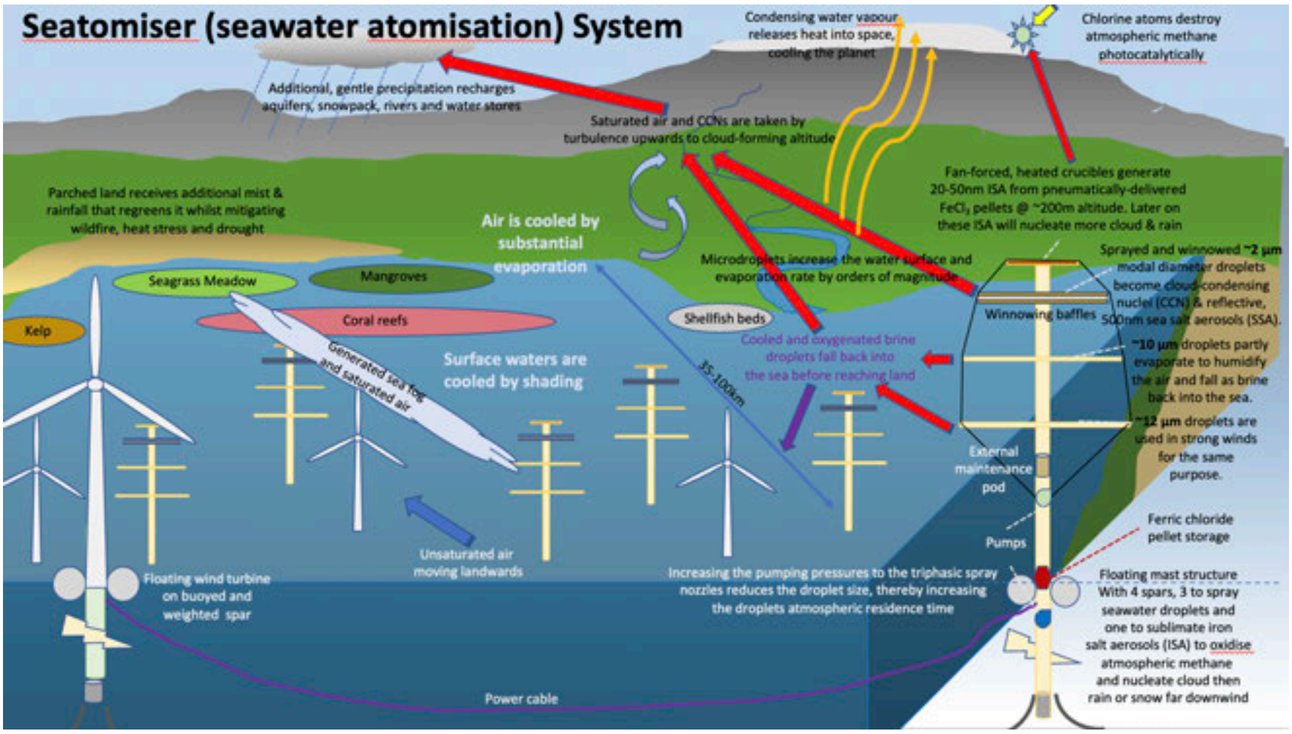
Innovation Dependencies

Successful modification of commercial spray nozzles to operate at much higher pressures and hence producing smaller droplet sizes.

Franz Oeste's ISA sublimation concept that generates effective, photocatalytic nanoparticles.

Extensive supporting documentation is available at https://www.noac.info/ReferencesDetail.aspx

Graphic



FIZTOPS

Short Description

A Fiztop (a top-shaped producer of fizzy bubbles) is a floating, lightweight, solar-powered unit designed to generate long-lived, reflective nanobubbles in the sea surface microlayer (SSML).

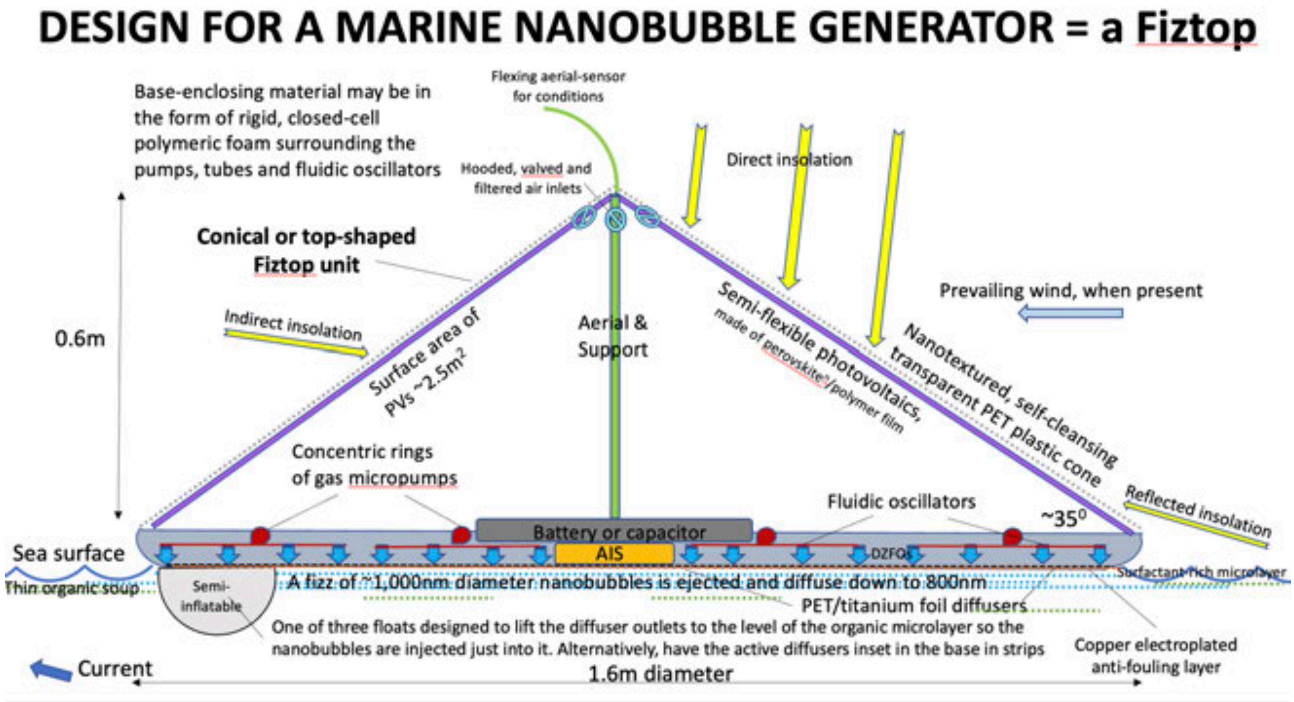
Key Functions

Surface ocean albedo increment to so reflect a portion of sunlight from the ocean surface that the water is cooled, thereby protecting ecologies such as coral reefs, seagrass meadows, kelp forests, mangroves, fish nurseries and shellfish beds from bleaching or overheating, and the water from stratifying and losing some of its oxygen and nutrient content. Increased ocean evaporation as sunlight that would otherwise heat the deeper water is refracted and reflected partly sidewise to warm the surface. Improved and extended atmospheric, shipping and marine sensing.

Innovation Dependencies

Perlemax DZFO technology; Winwick DZFO manufacture and diffuser technology; Flexible photovoltaics, Nanotextured self-cleaning surfaces, Artificial Intelligence System (AIS), comms and sensor technologies; and anti-fouling technology.

Graphic



ICE SHIELDS
Short Description
Thickening sea ice can be achieved when anchored, cold-adapted, Arctic wind turbines provide renewable energy to power low-lift, satellite seawater pumps and other system requirements. In the freezing season, AI-controlled pumping stations would optimise intermittent flows of seawater, first onto newly-formed sea ice, then onto each low-angle conical ice shield or lens as it built up – rather like how flowing lava down a slope can form a mountain. A frigid atmosphere and ice surface causes chilling from both above and below. This forms frazil ice crystals in the thinning, radial flow which attach themselves to the chilled ice below. The progressively chilling residual brine concentrates the dissolved carbon dioxide and oxygen in the brine (and may absorb more gas from the atmosphere), together with most of the salt from the seawater. Falling off the edge of each ice shield, the dense, 'brinefall' rivulets would take their contents directly to the seabed, where the CO_2 could react with seabed carbonates to form benign, long-lasting, dissolved bicarbonate, and the oxygenation could succour benthic life. Back of envelope calculation suggests that this method has the potential to sequester up to 16GtC/yr in Arctic abyssal waters alone. Brinefalls on a wide scale would also reinvigorate the overturning currents that keep our oceans productive and the climate and weather in much of the northern hemisphere benign. Ice shield-arrayed polar regions would help return the global climate to its pre-industrial happy state. It is estimated that ice could be thickened at an average rate of around 2cm/h in the freezing season, which is approximately 0.5m/day, or some 80m/yr.

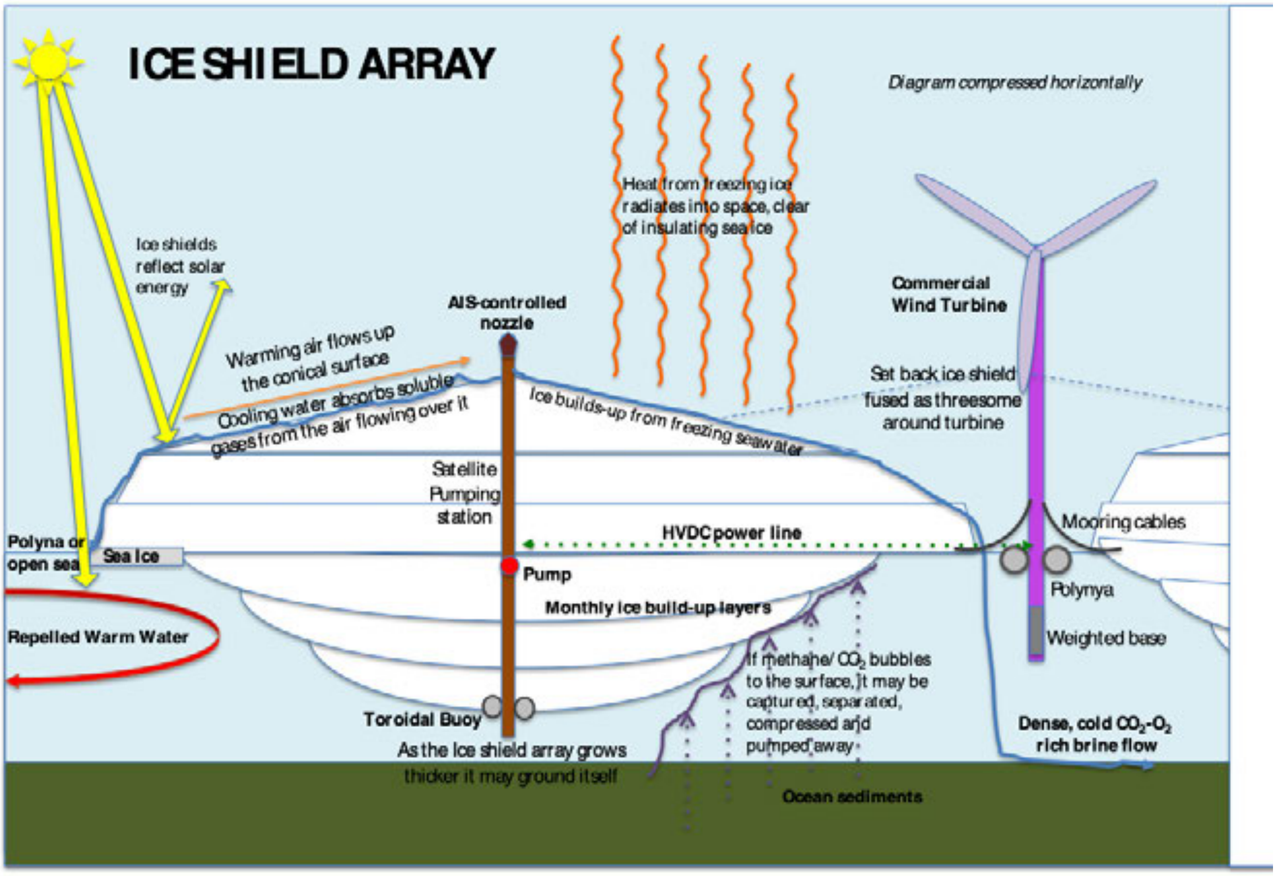
Over its extended, and possibly refurbished, life, a single, 2.5MW floating wind turbine might power the growth of up to 50, ~5km² ice shields in a linked array that could be grown and grounded in water up to several hundred metres deep. Designated channels and polynyas amongst the ice arrays would provide access for shipping and habitat for polar wildlife. Deep arrays would repel the intrusion of warm water into the Arctic Ocean, thereby reducing melt loss and glacial calving. Thermals derived from released ocean heat to the atmosphere in the cold and dark seasons would take the heat directly by convection to the tropopause, whence it would radiate into space, unhindered by the insulating greenhouse gases below it, thereby cooling the planet.

Increasing ice cover would reverse previous losses, whilst the semi-permanent increase in ice cover would effectively reflect warm season sunlight by its high albedo. Spare, warm season wind power might: be used to generate cooling marine cloud brightening; be taken to market by HVDC cable; be used to capture and process seabed emissions locally into no-drill natural gas, hydrogen, ammonia, nanocarbon products and vat protein; be used to generate iron salt aerosols (ISA) from sublimated ferric chloride pellets that destroy polluting atmospheric methane, nitrous oxide, black carbon, ozone, CFCs and smog by photo-catalysis; or else be used to pump Arctic river water south for use by industry, for irrigation, homes and habitat restoration.

Key Functions
Increasing polar and sub-polar albedo by restoring cryogenic habitat, whilst allowing ship and marine life all-year access to the regions; increasing thermal off-planet radiation; sequestering CO_2 safely and for centuries; reducing glacial loss; cooling the arctic and some sub-arctic regions; restoring benign hemispheric weather by increasing the polar vortices and the Atlantic Meridional Overturning Current (AMOC); preventing coastal erosion; helping to oxygenate the deep ocean; providing renewable energy; and allowing ebullient methane and CO_2 to be harvested before they reach the atmosphere.

Innovation Dependencies
Polar weatherisation of floating wind turbines and pumping stations; AIS capability to so vary the intermittent pumping regimes that linked and often-grounded ice shield arrays can be grown out from the shoreline; development of ebullient ocean gas harvesting, processing and transportation methods.

Graphics



ICE SHIELD ARRAY
Diagram compressed horizontally
Heat from freezing ice radiates into space, clear of insulating sea ice
Ice shields reflect solar energy
AIS-controlled nozzle
Commercial Wind Turbine
Warming air flows up the conical surface
Cooling water absorbs soluble gases from the air flowing over it
Ice builds-up from freezing seawater
Set back ice shield fused as threesome around turbine
Satellite Pumping station
HVDC power line
Mooring cables
Polyna or open sea
Sea Ice
Pump
Polynya
Monthly ice build-up layers
Repelled Warm Water
Weighted base
If methane/ CO_2 bubbles to the surface, it may be captured, separated, compressed and pumped away
Toroidal Buoy
Dense, cold CO_2-O_2 rich brine flow
As the ice shield array grows thicker it may ground itself
Ocean sediments

Attachment B

Cooling Currents

How to generate long-lived nanobubbles in the sea surface microlayer at scale and in numbers sufficient to cool overheated surface currents and coral reefs by their collective albedo.

Sev Clarke, December 2024

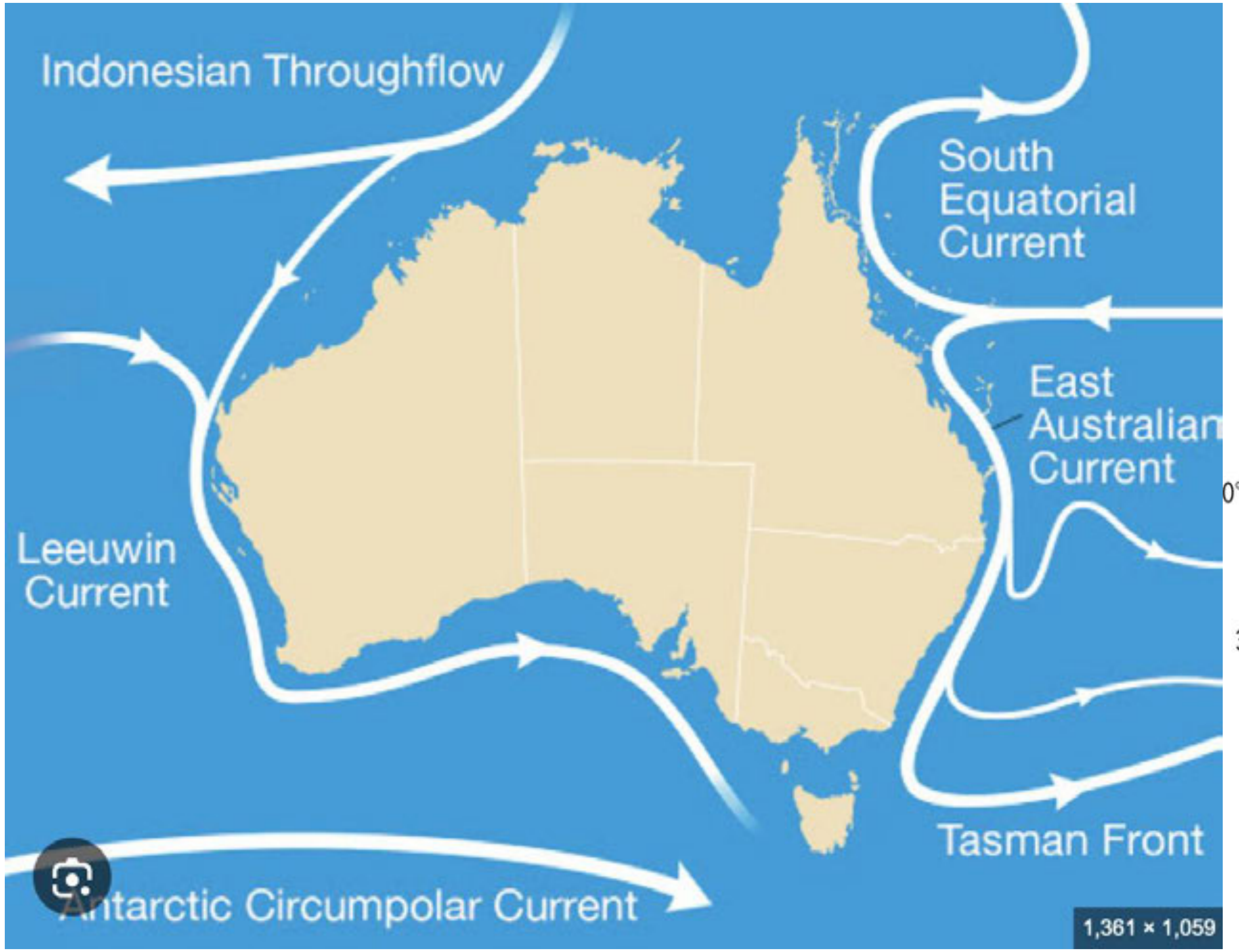
The Problem – and a solution for it

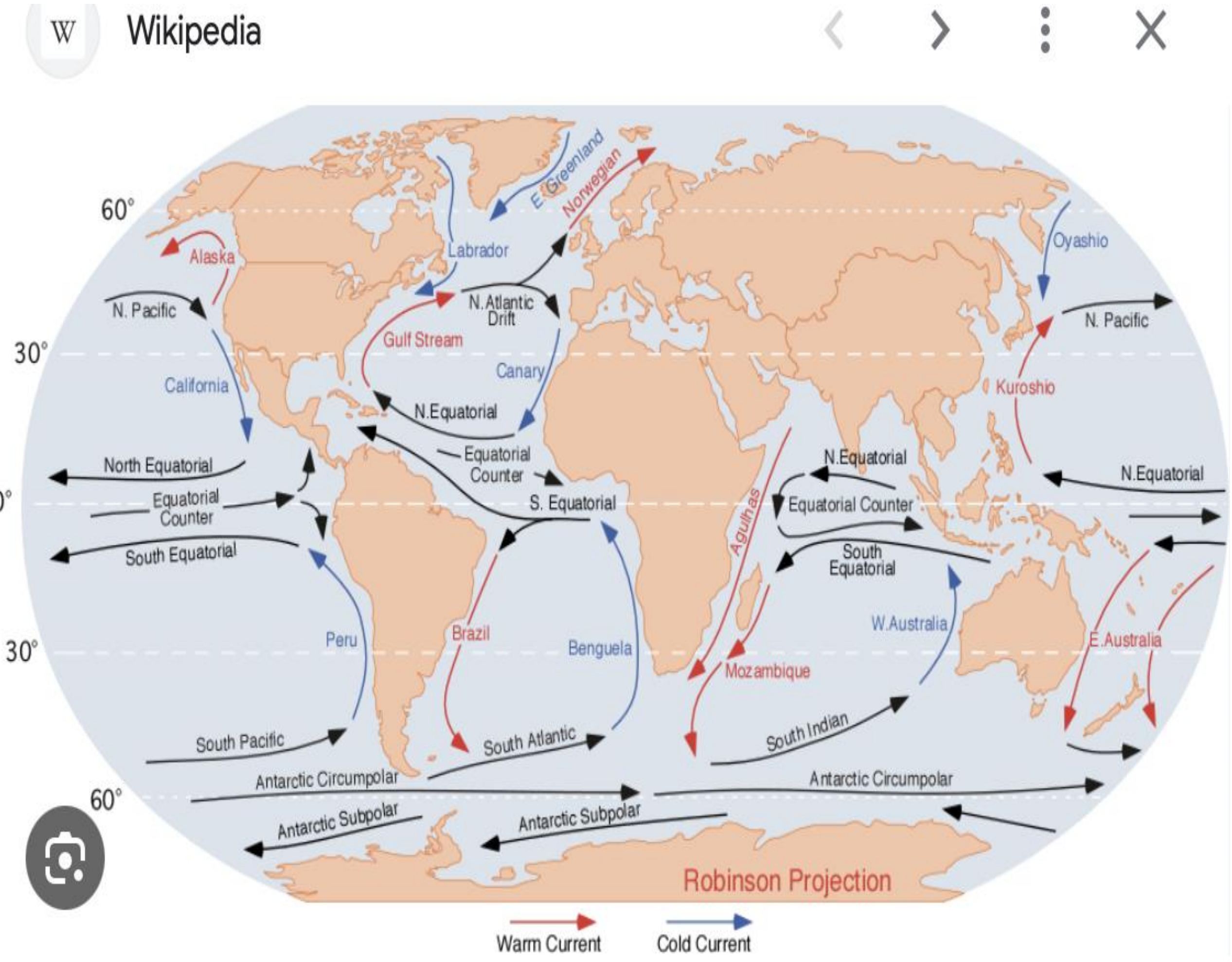
Efforts to prevent coral bleaching in the Great Barrier Reef and mitigating extreme weather events originating in the marine environment by means of Marine Cloud Brightening (MCB) have encountered difficulties, particularly in obtaining submicron sized seawater droplets or particulates in the requisite: narrow size distribution range, flow rate, energy source & cost, and areal coverage.

An alternative and complementary approach is to use the **inverse** of such droplets, namely long-lived nanobubbles in the sea surface microlayer (SSML). These might readily be generated by simple, carbon-ceramic-based air diffusers, fixed to a horizontally-spinning disc that was located just under the sea surface to help with bubble separation. This would help ensure that the rising (mainly low-micron) microbubbles lose gas by diffusion to become reflective, ocean-cooling nanobubbles at the SSML, surrounded by naturally-forming and protective multiple shells of phytoplankton surfactants, gas-saturated air, ions, and negative charges.

In warm, surface ocean currents, such as the: East Australian Current (EAC), South Equatorial, Leeuwin, Indonesian Throughflow, Gulf Stream, Agulhas, Mozambique, Brazil, Alaska, Kuroshio and Norwegian Currents, the albedo cooling effects might be expected to last for months and to extend thousands of kilometres down-current. The cooled waters might also be expected to percolate into shallow waters, such as those containing coral reefs, seagrass meadows, mollusc beds and fish hatcheries – and eventually into polar waters. Use might also be made of such ocean aerator installations placed in some of the great ocean gyres and countercurrent flows in tropical to temperate waters.

SUITABLE, WARM OCEAN CURRENTS
FOR NANOBUBBLE ALBEDO ENHANCEMENT





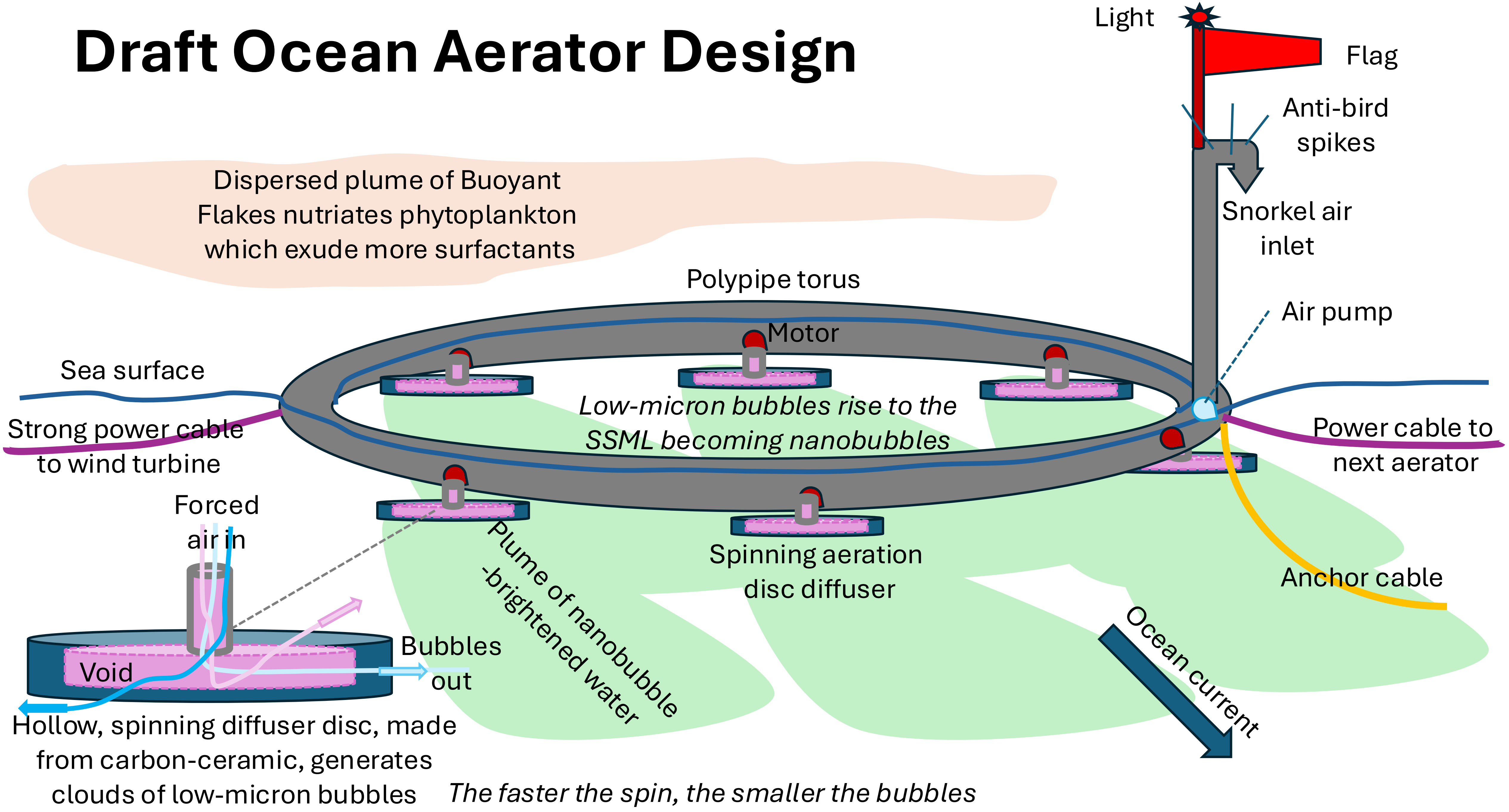
Proven and Safe Bubble Generation Technology

- Several companies have suitable technologies, see https://www.nanobubble.com.au https://oknozzle.com https://www.moleaer.com https://smi-inc.jp/en/nano-bubble-technology/ https://www.airywater.com https://www.nanokriti.com https://www.hollyep.com/new-technology-dissolved-oxygen-micro-nano-bubble-generator-product whilst the original development was done by Anzai Kantetsu, see https://www.youtube.com/watch?v=r4rJKypLijA
- These links show that making and applying nanobubbles at modest scale is now safe, accepted industrial and ecological practice; and thus might be scaled up to address the threat to the Great Barrier Reef (GBR) – and beyond.
- Some methods show applications well below the SSML whilst offering other co-benefits. However, we shall need to have the bubbles generated sideways into the water column, probably less than 0.5m deep, so that most of the bubbles rise to the SSML but not above it. This should ensure maximum solar reflectivity (albedo).
- It will also be advantageous if the probably-oligotrophic waters are previously and continuously nutrient-supplemented with my Buoyant Flakes so that there is a plentiful supply of phytoplanktonic surfactants necessary to give the now-nanobubbles an average lifetime of months.

Suggested Prototype Equipment

- A hollow, polymeric, disc-shaped spinning wheel, moulded from carbon-ceramic, diffuser material might be constructed so that pressurized air inside forms and separates low-micron bubbles in seawater. The hollow drive shaft of each disc conducts the necessary, pressurized airflow.
- The diffuser discs are attached as spinning nozzles to the underside of a hollow torus, 2-4m in diameter, formed from black polypipe, each disc having its own electrically-powered, tiny motor to spin it rapidly enough that the water flow rate prevents larger bubbles from forming.
- Each torus is made by using a three-way joiner, the upper pipe leading to an enclosed air pump and snorkel to provide the pressurized air, the other two making the polypipe into a circle. A flag, flagpole & flashing LED riding light are attached to warn of the unit's presence.
- Deployed at scale, lines of these anchored, **ocean aerators** would be connected in lines transverse to the ocean current by strong, submarine powerlines from a central, floating wind turbine that powers the installation. The catenary-forming powerlines between discs might eventually be made from tough, Zylon polymer cable surrounding a conductor made from graphene or carbon nanotubes. However, the prototype might be made from more standard materials and a lesser power source.

Draft Ocean Aerator Design



Advantages of the Ocean Aerator Method

- Compared to Marine Cloud Brightening (MCB) where the Cloud Condensation Nuclei (CCN) have an average atmospheric lifetime of some 3-4 days, nanobubbles in the SSML would have an average life of 3-4 months – **a 30-fold advantage**.
- The particle size distribution requirements are far less onerous than for MCB.
- Because surface ocean currents are the main distribution means, initial dissemination for GBR purposes could be from just one or a few, static locations and only to the readily accessible ocean surface.
- Because air is the active medium, filtration and clogging are not issues, and biofouling of the fast-spinning diffuser discs may be self-limiting.
- Power provision is hardly problematic as operation can simply cease when there is insufficient wind; and a modern, floating wind turbine should be capable of powering a line of many ocean aerators whose nanobubble products might brighten ten thousand square kilometres of ocean.
- Albedo change measurement, reporting and verification (MRV) should not be difficult using largely satellite imagery.
- It may be possible to arrange power from some existing wind farms, particularly when it is in excess or cheap. The low capital cost of the aerator units should allow them to be activated remotely and sporadically.

Co-benefits of the Method

- Substantial reoxygenation of the surface waters should result from nanobubble injection.
- The combination of nutrient supplementation and the additional availability of dissolved nitrogen in the SSML should allow substantial increase in the diazotrophic production of nitrates.
- Cooling the water by solar reflection should decrease thermal stratification and increase the uptake of CO2 and oxygen.
- Storm and hurricane strength and possibly frequency should be reduced by way of reduced surface ocean temperatures.
- Marine species would not need to move polewards so fast, if at all.
- Polar ice would not melt so fast and might even partially recover.

Potential Risks of Application

- Cooling only the warm surface currents, rather than the whole ocean surface, might affect terrestrial rainfall patterns – for good or ill. Modelling and re-allocating albedo ocean cooling should be able to minimize some adverse effects.
- Navigation around floating installations and cables would be required.
- Broken, live cables might needs be shut down rapidly – though they would likely be less dangerous than is lightning strike on the ocean.
- Sharks might attack the power cables, mistaking the electrical currents in them for edible life.
- Anchors might drag and aerator units might break loose.
- The feasibility of deep anchoring using Zylon or graphene cable is yet TBD.
- Private funding may be problematic as cooling credits for industry may be difficult to arrange, and the approval and governance of national funding could sometimes be contentious.

Techno-economic Assessment (TEA)Parameters

- The capital and operating costs of floating, offshore wind farms are well-known – as is the annual power likely to be delivered in a given oceanic region by a single turbine of optimal size there.
- The effectiveness of the Buoyant Flakes method is now being investigated by a consortium of five, international research agencies – with promising results.
- The cost of a single ocean aerator system and its infrastructure may be estimated using standard engineering costing methods, whilst improvements to its design, manufacture, deployment, maintenance and replacement cost-effectiveness at scale under the Experience Curve should not be too difficult.
- The flow rate of low-micron bubbles generated by a single, spinning aeration disc and reaching the SSML as nanobubbles may be determined and optimized by experiment, as may be the average life of a SSML nanobubble in surface water containing different concentrations of, say, diatoms, plus the albedo enhancement caused by such releases.
- Together, such parameters should give TEAs on which to base Earth Systems Modelling and hence the viability, scalability, cost, timeliness and acceptability of the approach.