Large Scale Ocean Based Waterbag Photo-Bioreactor for Algae Production

Preliminary Outline of Concept, March 2009

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Summary

- This paper presents initial concepts for a commercially profitable new technology, with processes and methods to remove anthropogenic greenhouse gases from the atmosphere to improve the stability of the Earth's climate.
- Large scale ocean based algae farming using waterbag photo-bioreactors is a technology with potential to provide the best single possible contributor to efforts to reverse and control global climate change by capturing, storing and using atmospheric carbon dioxide. The aim is to develop a simple system using bio-mimicry with rapid potential for replication on a mega scale.
- The claim is that very large areas of the ocean can be made productive using waterbag algae photo-bioreactors at low cost, with high benefits for energy production, food production and climate security.
- This document provides a preliminary explanation of this new innovative technology to reverse global warming, outlining concepts which appear to be scientifically and commercially sound, but which require detailed technical examination and development.
- Large scale ocean based algae production has strong potential to hold atmospheric carbon dioxide below 400 parts per million and help drive it below 300 parts per million this century while producing a range of related large economic, social and environmental benefits.

Key points:

1. The black areas shown below are known as 'ocean deserts' or 'dead zones' because of their low chlorophyll production. They occupy more than fifty million square kilometres of the planet, about seven times the size of Australia. The technology promoted here, while also suitable for other ocean areas, primarily aims to turn these large ocean areas into high productivity fishing and bio-diesel manufacturing zones, with large environmental and climate security co-benefits.

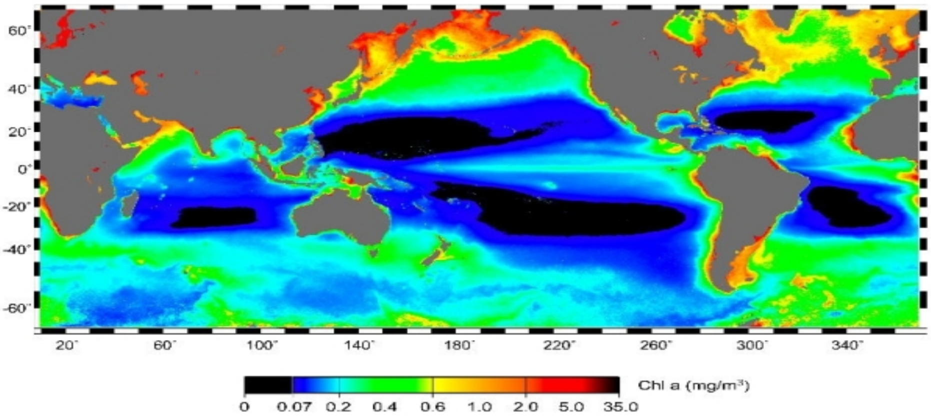


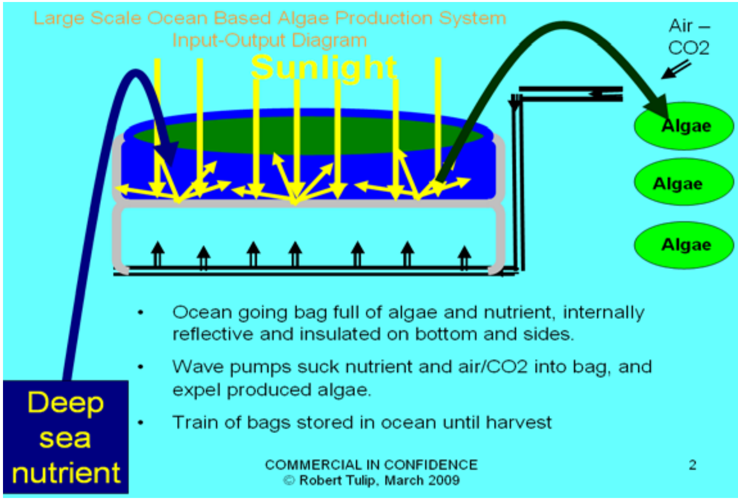
Figure 1.

2. The ocean is immense, covering 71% of the planetary surface at average depth of about four kilometres. The premise of this proposal is that large scale CO_2 capture can be implemented globally in the ocean much more easily than on land, due to competing uses and expense for land and the feasibility and low cost of this proposed technological solution.

3. The relative density of fresh water and ocean water is 40:41. The lighter density of fresh water enables fabric containers of fresh water to float at sea as described at www.waterbag.com. Waterbags can be joined in long trains providing a robust, low energy method for large scale fresh water transport and storage. Laboratory tests at the Massachusetts Institute of Technology found

that trains of polymer waterbags of size up to one gigalitre would withstand ocean swells of up to 30 metres by becoming part of the surrounding ocean wave. Economic analysis indicates that waterbag technology will provide high quality drinking water in flexible quantities and locations at competitive price with very low energy cost.

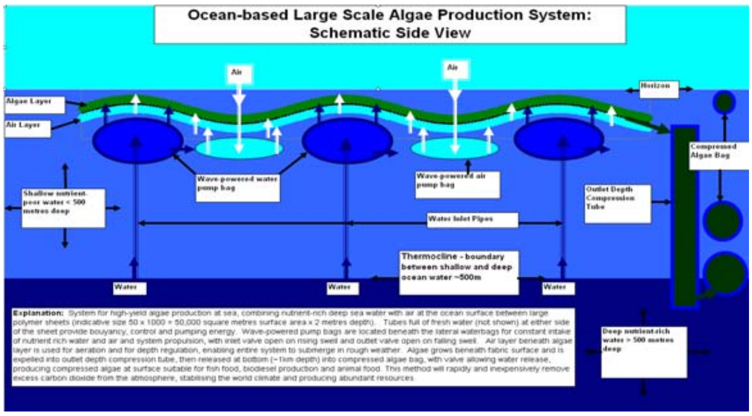
Figure 2.



4. The concept outlined here is a large scale potential spin-off of waterbag technology for ocean based algae farming, with major benefits for global climate security. Using waterbag technology, ocean based 'photo-bioreactors' can be built to combine all inputs needed for algae production using only renewable energy inputs, and providing a range of useful outputs. Figure 2 provides a very simplified schematic diagram of the process.

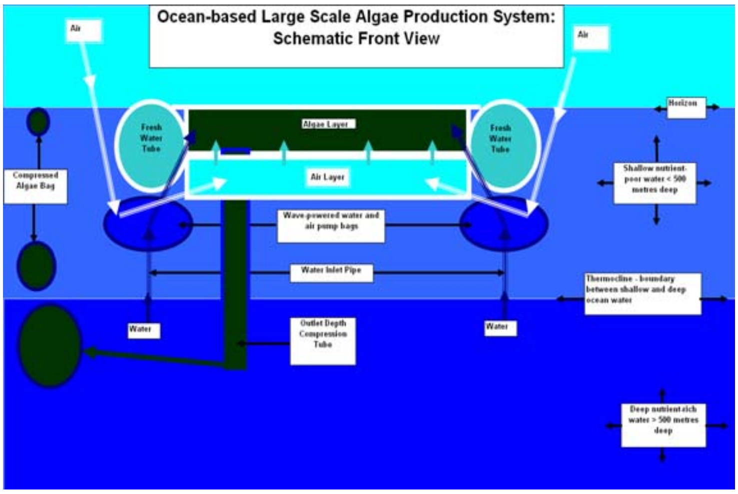
Figure 3: Side View

(larger versions of Figure 3 and 4 are attached)



5. A preliminary concept to use waterbags as a photo-bioreactor involves two parallel waterbag trains about 50 metres apart, each of indicative diameter ten metres and length one kilometre, joined along their entire length by three layers of fabric sheet. A system of this size can function as an ocean-going photo-bioreactor of size 5 hectares = 10 acres.

Figure 4: Front View



6. This system can be optimized to combine nutrient, carbon dioxide, algae and water to mimic natural production of algae blooms in the ocean, using deep ocean water as feedstock, using the waterbags' vertical motion in the ocean waves as a power source for pumping and movement.

7. Inputs enter in secondary pumping bags located beneath the fresh water lateral bags at either side of the system. Nutrient-rich water is pumped by wave power from the deep ocean to the surface, where it is mixed with air, also pumped into the system as shown above. Aerated deep ocean water flows across the surface of the system, with further CO_2 and nutrient added along the length of the system, to grow a controlled algal bloom that is expelled at the rear, where it is either released to the ocean as fish food or de-watered and collected into fabric bags for transport to a refinery.

8. Algae is produced between the top two fabric layers, while the level between the bottom two fabric layers is filled with air. The top sheet, at the ocean surface, protects the entire system to

contain algae within. A one-way mirror polymer would hold the energy of available sunlight within the algae layer. The middle sheet, at indicative depth of three metres below the surface, is insulated and reflective to trap all incoming sunlight and heat in the algae layer above it. The middle sheet has valves spaced equally along it to enable air from the bottom layer to bubble up into the algae layer above.

9. The space between the bottom two layers contains air, continually added by wave pumps. This air layer enables optimum CO2 input to the algae photo-bioreactor above. The air layer also regulates the depth at which the system sits in the surrounding ocean. Pumping in more air enables the system to ride high on the swell in calm weather for maximum algae production, while removal of air during rough weather sinks the system temporarily below the surface.

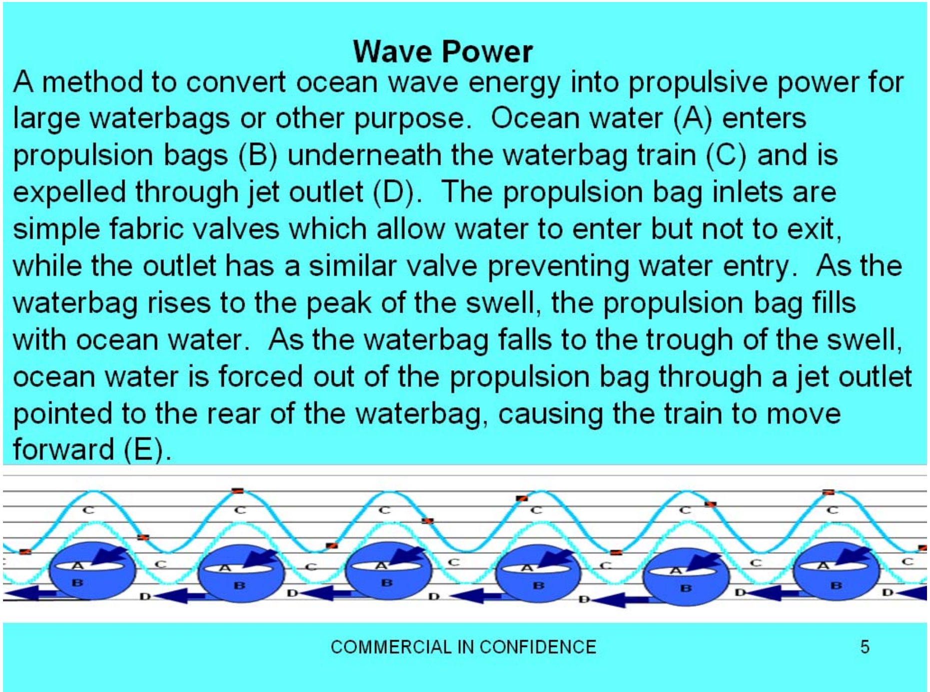


Figure 5

10. The wave pump system is shown here. Submarine bags under a long fresh water bag are equipped with entry and exit valves. These valves can propel the bag, converting wave energy to propulsive force, or pump water or air into the algae photo-bioreactor adjacent to the waterbag.

11. This system would ‘plough the sea’, turning the massive barren areas in the world oceans into productive fishing grounds. NASA satellite data[1] shows that low productivity ocean deserts, areas with no surface chlorophyll, have reached 51 million square kilometers in size worldwide and are expanding, with diagrams[2] clearly indicating location and size. The analysis claims these unproductive barren ocean areas have grown by more than six million square kilometres in the last decade due to global warming.

12. At indicative unit rate of twelve tons of algae per day per system, or 4000 tons per year, one million waterbag photo-bioreactor units would produce four gigatonnes of algae per year, with each unit traversing an average of 50 square kilometres of available ocean desert. This production level would rapidly stabilize and reduce atmospheric carbon concentration, while producing economically valuable outputs.

13. Using a rough initial estimate that each ton of algae could provide 300 litres of diesel fuel, worth $150 net at $0.50 per litre, and other products, primarily protein and carbohydrate, with net commodity value of $50 per ton, production of 4000 tons of algae at $200 per ton would yield annual value of $800,000, plus carbon sequestration and fish food co-benefits.

14. At indicative estimate cost of $10 per square metre of polymer fabric, a five hectare system using 20 hectares of fabric (three layers plus bags and pipes) would cost around $2 million for fabric and one million for control systems. On this rough costing total of $3 million, the system would repay its capital cost in four years. The period would be shorter if any CO2 sequestration subsidies are available. It would provide ongoing assured high dividends due to low operation cost.

[1] http://environmentalism.suite101.com/article.cfm/ocean_desert_areas_are_escalating
[2] http://images.suite101.com/328567_com_globe2.jpg

15. Options for use of algae from waterbag photo-bioreactors include fish food, land based fertilizer, and bio-diesel production. Produced algae could either be released into the ocean or captured in waterbags for transport to a refinery. The climate security goal is served by providing a large scale economically productive and rapid way to remove carbon from the air.

16. Use for food production would involve release of fingerlings into the algae production layer, and putting a large net around the entire system. All fish in the system will have a ready abundant food source from produced algae, and can be harvested at optimum size. Stocking the system at the head with fish spawn will enable fish to grow in the bioreactor with limited predation and abundant food. This method will provide an ongoing food source for the fish when they are released into the open ocean, as it mimics the upwelling of deep ocean currents to make the ocean desert bloom at low cost. Use of algae for fish food would provide a major additional food source for the world, enabling reduced harvesting of current wild fish stocks and providing improved food security.

17. Produced algae can be de-watered and concentrated for transport as follows. At the system exit point, the produced algae bloom flows into a very deep fabric container, an ocean dam up to a kilometre deep. At the base of this container, algated water flows out into smaller bags which when full are sealed and released. These bags have a release membrane which will allow water to pass but not algae. This smaller bag is connected to another chamber filled with compressed air. On release from the base of the deep dam the bag of algae-rich water produced by the photo-bioreactor floats to the ocean surface. The decreasing external water pressure during the rise causes expulsion of water from the bag through the release membrane while keeping algae inside, resulting in compressed de-watered algae at the ocean surface as a final product. These bags can be connected in trains like railroad box cars and towed to land-based oil refineries and fertilizer production plants.

18. Ocean wave energy can be harnessed by the waterbag bioreactor through four key functions:

a. pumping nutrient-rich water from below the thermocline to the surface to pass through the photo-bioreactor, mimicking the natural creation of algal blooms from upwelling of deep ocean currents;

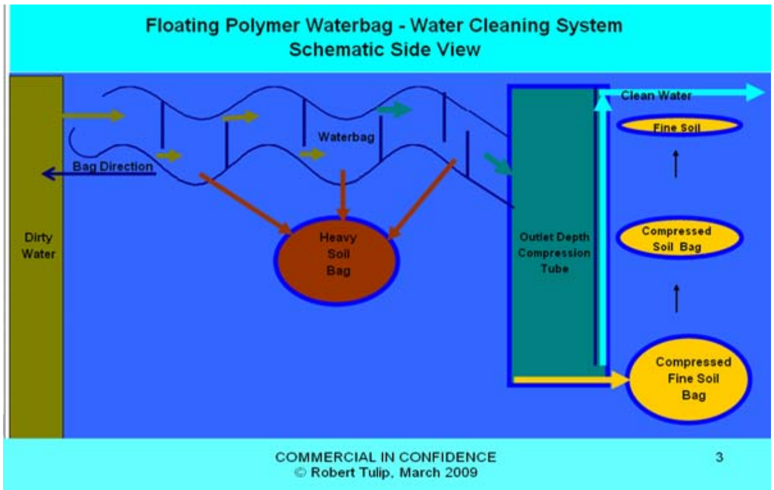
b. pumping air into the base of the photo-bioreactor along its length to enable CO2 absorption through algae photosynthesis;

c. converting wave energy into propulsive power to enable the waterbag train to move through the ocean.

d. Algae centrifugation and oil expulsion, providing motor energy by using waterbag wave motion to power piston engines.

19. In the event of storms, the entire system can be sunk to a depth at which no damage is incurred by expelling air from the lower air layer. In good weather, the air layer can be filled so the system rides high on the swell.

20. Waterbag photo-bioreactors will also be suitable to clean and restore the ‘dead zones’ at the mouths of major rivers such as the Mississippi in the Gulf of Mexico and Queensland rivers at the Great Barrier Reef, by targeting areas of highest nutrient load and converting this nutrient into controllable algae production instead of allowing the pollution to kill existing ecosystems, as shown here – Figure 6.



21. The system will also have the local benefit of cooling the ocean water beneath and around it by using all incoming sunlight for

algae production, with benefits for reducing environmental shocks where water temperature is rising due to global warming in places such as the Great Barrier Reef.

22. Waterbag photo-bioreactors can be considered as normal maritime vessels. A control room on top of the vessel would be required for steering like a normal ocean tanker, and for algae production management. The vessel could also be used for containerized transport on suitable routes. For example systems located in the North Pacific Ocean could follow the path of the North Pacific Current between Japan and the USA.

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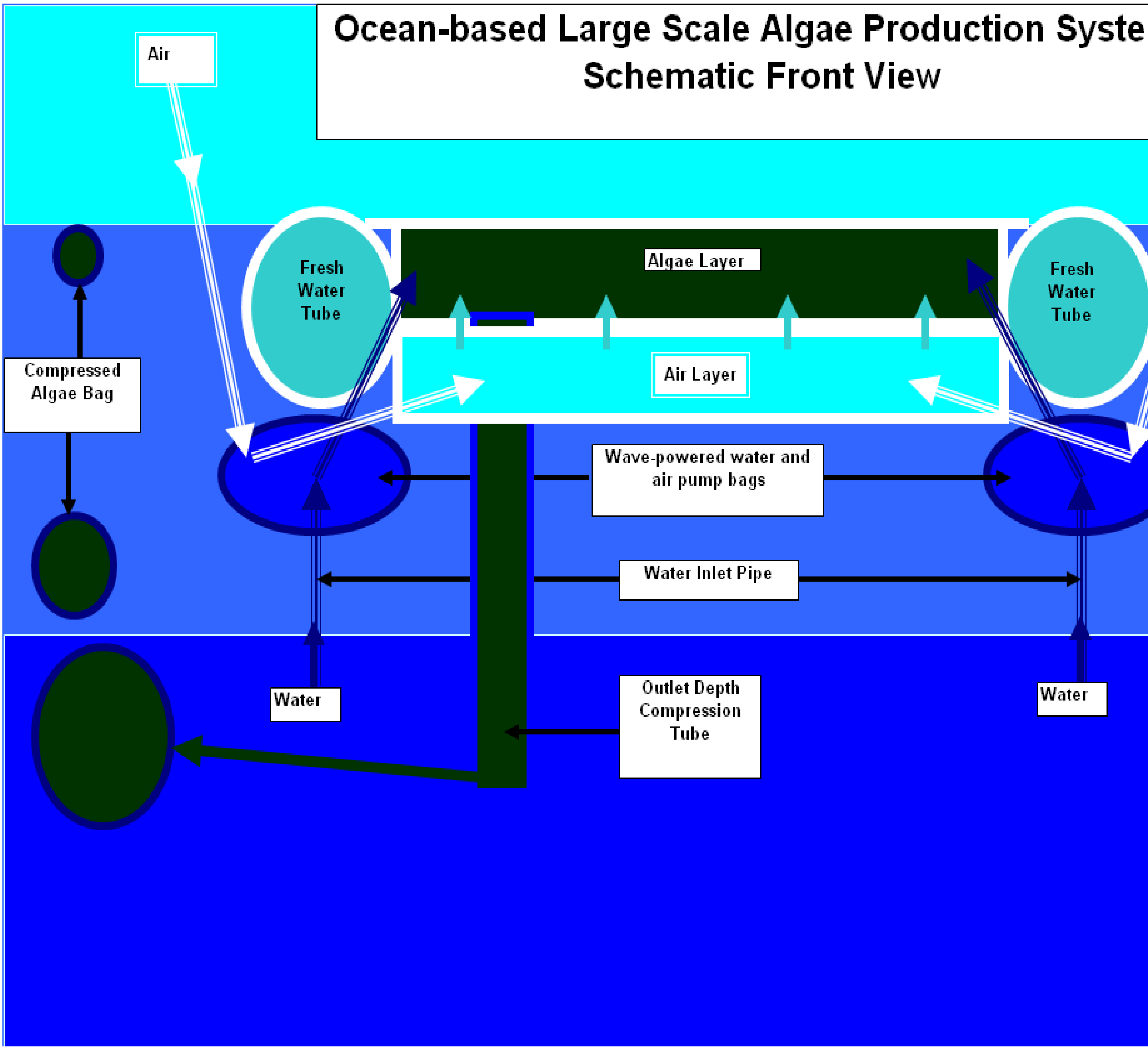
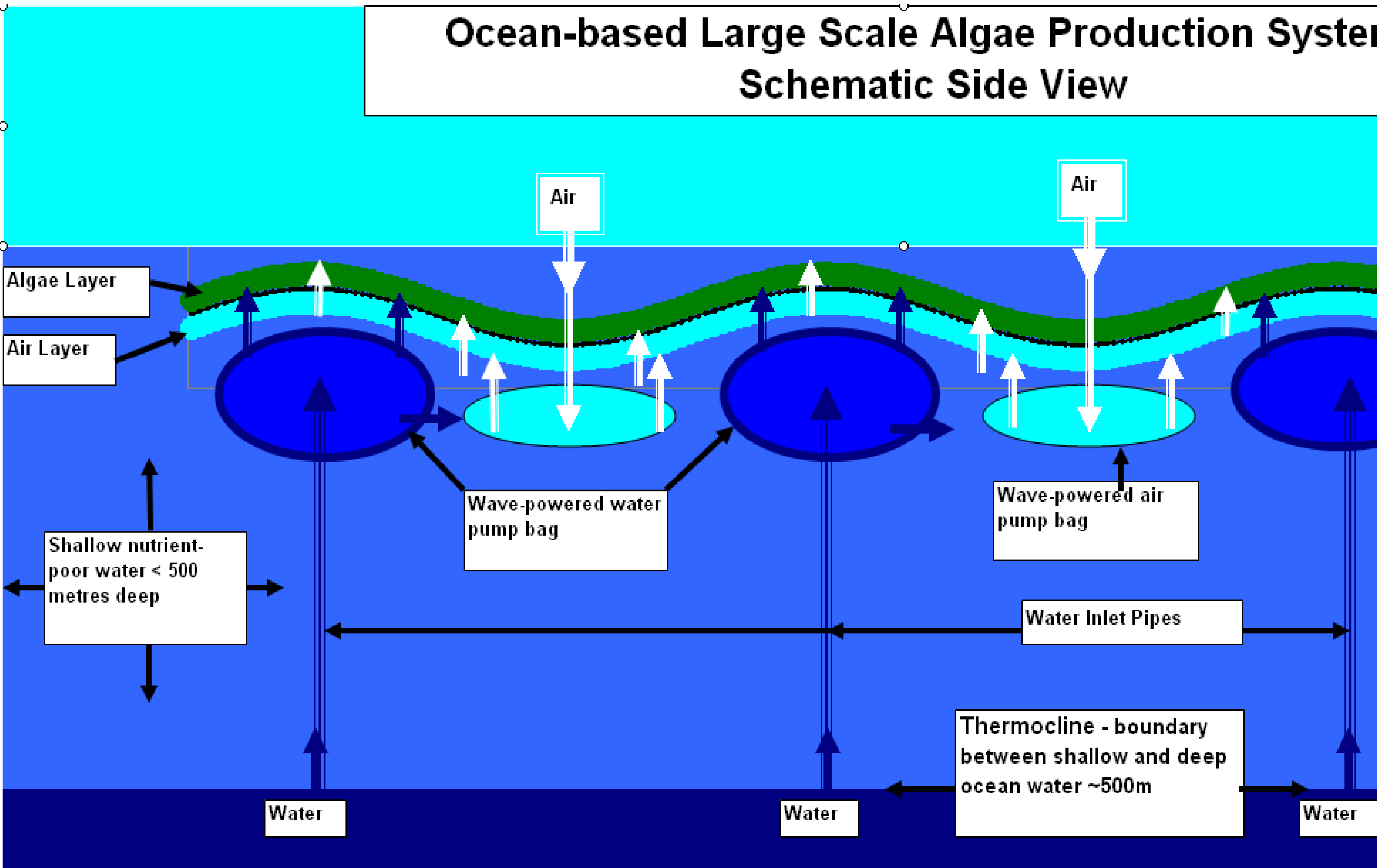

Ocean-based Large Scale Algae Production Syste
Schematic Front View
Air
Fresh Water Tube
Algae Layer
Fresh Water Tube
Compressed Algae Bag
Air Layer
Wave-powered water and air pump bags
Water Inlet Pipe
Water
Outlet Depth Compression Tube
Water



Explanation: System for high-yield algae production at sea, combining nutrient-rich deep sea water with air at the ocean surface between large polymer sheets (indicative size 50 x 1000 = 50,000 square metres surface area x 2 metres depth). Tubes full of fresh water (not shown) at either side of the sheet provide bouyancy, control and pumping energy. Wave-powered pump bags are located beneath the lateral waterbags for constant intake of nutrient rich water and air and system propulsion, with inlet valve open on rising swell and outlet valve open on falling swell. Air layer beneath algae layer is used for aeration and for depth regulation, enabling entire system to submerge in rough weather. Algae grows beneath fabric surface and is expelled into outlet depth compression tube, then released at bottom (~1km depth) into compressed algae bag, with valve allowing water release, producing compressed algae at surface suitable for fish food, biodiesel production and animal food. This method will rapidly and inexpensively remove excess carbon dioxide from the atmosphere, stabilising the world climate and producing abundant resources.