# Glacial Solutions to Climate Change

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Progressive loss of Arctic ice and continental snowpack threaten Life on Earth in many ways. There is a way to increase ice cover that can work, even whilst a measure of global warming continues. It can be seen to operate in the current increase in Antarctic sea ice, where increasingly strong circumpolar winds break up the forming ice pack, thereby allowing seawater to well up between broken and tipped-up floes and thus to freeze into much thicker ice than would have been allowed by the insulating effect of integral sea ice (1, 6).

We probably do not wish to increase polar storms to obtain this effect, particularly as it does not work as well in the Arctic. This is so because, whilst the Antarctic is a large continent surrounded by ocean, the Arctic is a large ocean surrounded by land. This and other differences cause different outcomes. However, we can, and have, caused sea ice to thicken by the simple expedient of pumping seawater onto existing sea ice (1, 2, 3), whence it will readily freeze throughout nine months of the year into ice as thick almost as we could wish it – up to a kilometre. Thus, we should be able to glaciate polar regions faster than they currently melt. This could be done using modifications to offshore wind turbine technology. Moreover, renewable power left over from pumping can be sold to help fund the enterprise, or to provide other benefits.

## Introduction

Ecological surveys and exploration companies have for many years drilled and thickened sea ice to provide platforms for their operations (3, 4, 5). Their requirements have typically been met by thickenings up to only ten or so metres. Various methods have been used to do this, from snow-making machines to simple pumping and flooding. However, if a buoy-mounted wind turbine and pumping system is used (see attachment IceShieldStrategyv17.docx), the progressively ice-encased installation can form its own lens-shaped iceberg with a tenth of its mass above sea level and the rest below. With a tall or extendable support column for the blades and nacelle (the structure that encloses the gearing, controls and generator), given time the growing iceberg, or ice shield, could be securely grounded in water up to ~900m deep.

## Prospective applications

Ice shields could be grown in linked arrays or ranges to provide a mix of services that includes:

* Cooling the world by means of increasing the polar albedo (reflectiveness) of its dark waters via the generation of semi-permanent, ice-white shields
* Using long-wave radiation and air convection from the seawater freezing on top of the ice to transport excess global heat efficiently out into space. This heat bypasses the insulation caused by the sea ice, clouds and greenhouse gases. Effectively, it creates a thermal bridge between the ocean water under the ice and stratospheric space (1)
* Preventing the inflow of warming waters into the Arctic Ocean by means of ice barriers
* Reversing the loss of ice floe habitat, whilst providing polynas (open spaces between floes) to allow air-breathing ‘marine’ life to flourish
* Placing a thick, icy blanket over Arctic sediments in danger of catastrophic methane eruption
* Using the ‘waffled’ arrays of lenticular ice shields to concentrate any residual methane emissions to areas where they can be harvested. There are enough frozen methane clathrates in Arctic sediments to be used as a low-carbon transition fuel and a source of chemical feedstock to replace coal usage globally. Moreover, methane should be used before coal and oil because it is far more vulnerable to global warming and is more dangerous globally if emitted
* Providing ice-based infrastructure for use by scientific teams, industry and tourism, whilst preserving shipping and wildlife migration access via preselected routes. One such structure might be a largely-ice road/rail connecting Siberia to Alaska (7)
* Stabilising polar glaciers by shielding them from warming and lubricating water by means of growing and grounding massive ice shield barriers
* By means of ice dams and/or pumps utilising renewable energy, turning portions of some Arctic rivers south to where their otherwise wasted water is desperately needed, rather than harmfully letting it warm, de-gas, and de-ice the Arctic Ocean
* Preventing the breakup of integral sea ice caused by deeply penetrating swells of over 3m in height (8)
* Stabilising the polar vortices and jet stream, thereby reversing the increase in extreme weather events (9)
* Providing immense amounts of renewable energy and natural gas to the world, probably fairly cheaply and at minimal environmental cost.

## Scientific debate

Whilst considerable use has been made of ice roads, ice bridges, ice causeways, ice landing strips, ice-based pipelines, ice lakes, ice sculptures, preservation in ice, ice islands, ice dams, ice buildings, ice infrastructure, and thermal siphons to make these last longer, there has been little or no debate regarding the prospective uses of ice shield arrays, ice barriers, individually-grown icebergs, and ice shields or lenses – some of which have been briefly described above. Presumably, this has been the case because it was not imagined previously that linked and glacially-large ice shields might be grown conically on-site, using economical and sustainable energy, from offshore wind turbines mounted on effectively disposable and benign, toroidal, ferro-concrete buoys, and using the water from under seasonal or permanent, insulating ice cover as the raw construction material.

## Demonstration project

A representative project would be the construction of a 100km long transport causeway linking Siberia to Alaska via the two Diomede Islands in the Bering Strait. A conventional or composite, cold-adapted, 4km road/rail bridge would link the rocky islands, providing ship passage beneath it. Two ice shield ranges, each perhaps nearly three ice shields wide, would be grown and grounded there in a single cold season to link each island to its respective continent. Thermosiphons, like those cooling permafrost infrastructure, would be installed to keep the ice frozen in the brief warm season. The ice shields would be graded smooth between the rows of wind turbines, and both road and railway constructed. Additional land-based infrastructure would be constructed to link to the national transport, power and communications infrastructures of North America, Russia, and possibly China. These are not costed here.

The likely benefits would include:

* Preventing warm Pacific surface currents from warming the Arctic Ocean and sediments, releasing methane, and reducing Arctic ice and albedo
* Linking the two continents by ‘land’
* A demonstration project that provided baseline, costs, results, modelling confirmation, and the lessons learnt necessary for the improvement and evaluation of other, much larger polar ice shield projects to address global warming
* A project that is relatively small and safe, staged, likely to be internationally acceptable, providing net environmental benefits, and being early reversible
* Ability to pilot single and clusters of ice shield effects and parameters at various locations
* The more expensive parts of the construction, the bridge and transportation elements, would only be constructed after the ice causeway had proven itself.

Order of magnitude causeway parameters are:

* Average water depth 50m
* Ice volume of causeways 17km3
* Water-lift energy required, 3,000Gj
* Buoyant wind turbine installations and linkages, $0.7b
* Bridge cost, $3.5b
* Causeway road & railway cost, $1.5b

## Issues for further consideration

Now that the imaginative leap has been made, modelling, R&D, design, global discussion, and both cautious and transparent experimentation under appropriate governance can now take place. These should help determine: the likely results, including ecological and climate effects; emerging threats and opportunities; risk management issues; desirable policy; monitoring regime; how best to address any legal or social hurdles; financial issue resolution; how best to harness global talent and enterprise, and thereby to optimise ice shield performance and outcomes; and the organisational arrangements necessary to make good collective decisions regarding project allocation, equity, funding, and progressive implementation in the light of looming environmental catastrophes and the other methods of addressing them.

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