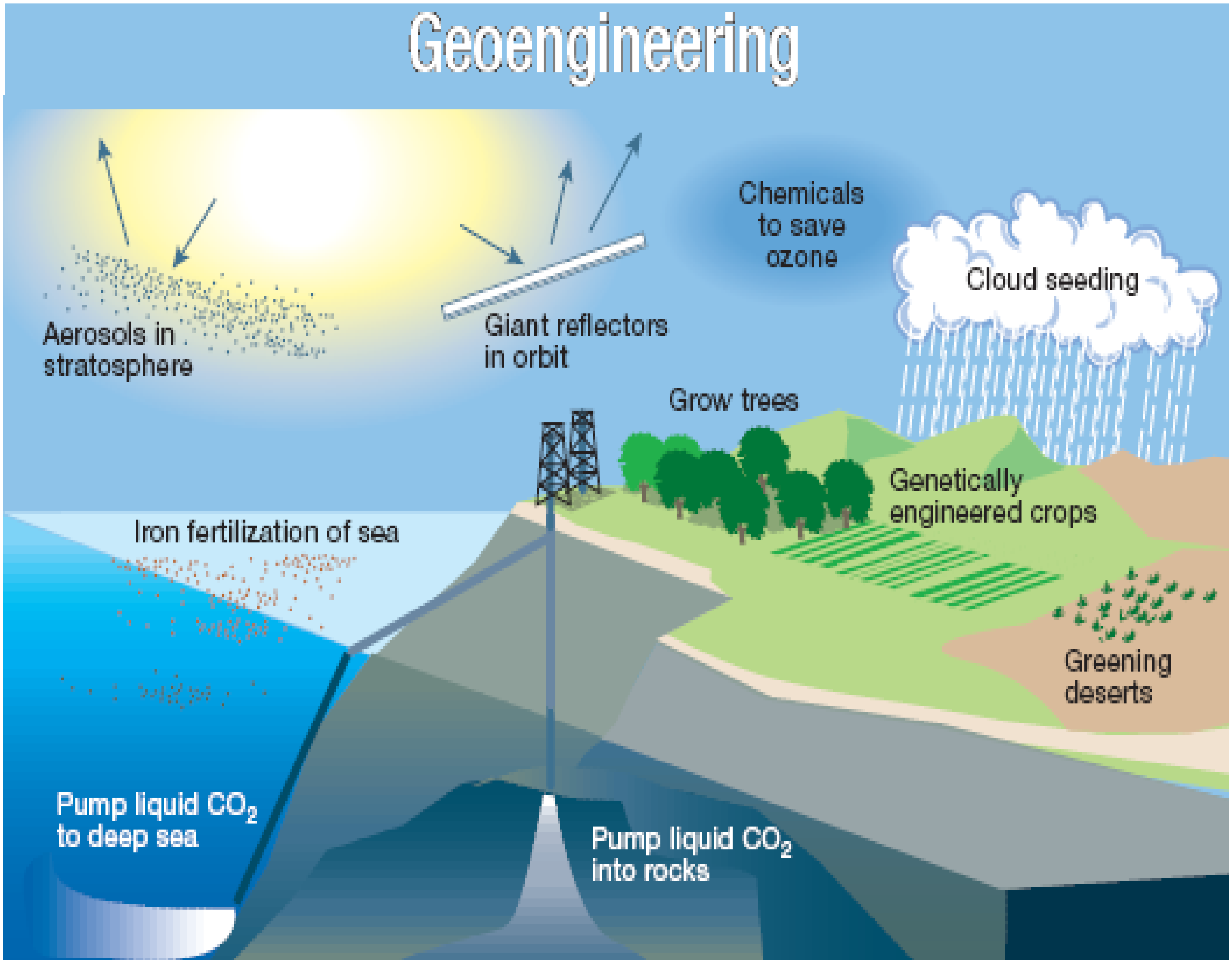

Schematic representation of various climate-engineering proposals (courtesy B. Matthews).

insight feature
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David W. Keith

Geoengineering is planetary-scale environmental engineering, particularly engineering aimed at counteracting the undesired side effects of other human activities 1. The term has usually been applied to proposals for limiting the climatic impact of industrial CO2 emissions by countervailing measures such as the construction of space-based solar shields. Scale and intent are both central to the common meaning of geoengineering as the following examples demonstrate. First, intent without scale: ornamental gardening is the intentional manipulation of the environment to suit human desires, yet it is not geoengineering because neither the intended nor the realized effect is large-scale. Second, scale without intent: anthropogenic CO_2 emissions will change global climate, yet they are not geoengineering because they are a side effect of the use of fossil fuels to provide energy services. The distinction between geoengineering and more conventional responses to the CO_2–climate problem is fuzzy. Geoengineering has become a label for technologically overreaching proposals that are omitted from serious consideration in climate assessments. For example, few would object to applying the label to the first pair of examples below, but neither proposal rates serious consideration among climate policy-makers. Conversely, the second pair do receive serious consideration but few would call them geoengineering.

Geoengineering proposals:

Enhancing oceanic sinks Concept.

Fertilizing the 'biological pump' may enhance the flux of carbon into the oceans that maintains the disequilibrium in CO_2 concentration between the atmosphere and the deep ocean. While use of nitrogen and phosphorus has been proposed, iron fertilization is the salient possibility because the ratio of iron addition to carbon fixation is very large (the Fe:C ratio is ~1:104 whereas for N:C it is ~1:6). Status. Iron-fertilization experiments have produced marked increases in oceanic productivity2, and surveys have shown that biological productivity is iron-limited over substantial areas3. Although enhancement of surface productivity is possible, increasing the carbon flux into the deep ocean is highly uncertain — models suggest that even if iron fertilization was used at the largest possible scale the carbon flux would not exceed ~1 GtC yr11. And problems abound, as iron fertilization could produce anoxia in large regions of the deep ocean.

Shielding some sunlight Concept.

Warming due to anthropogenicgreenhouse gases can be countered by deploying systems in the stratosphere or in space that scatter sunlight away from the planet. Stratospheric scatters are much cheaper but entail risks to stratospheric chemistry; space-based systems offer an expensive but clean alteration of the solar 'constant'. Status Analysis has shown that it is possible to dramatically reduce the required mass and thus the cost of both scattering systems 4. It had long been suggested that changes to the solar constant would compensate only poorly for the climatic effects of increased CO_2, even if mean surface temperature was accurately controlled. But a recent climate model experiment indicates that reduction of solar input can compensate for increased CO_2 with remarkable fidelity[5].

Ambiguous Cases Enhancing terrestrial sinks Concept.

Given the substantial human control over the terrestrial biosphere, the large natural carbon fluxes between atmosphere and terrestrial biosphere provide a powerful lever for manipulating atmospheric CO_2. A great diversity of methods have been proposed to exploit this leverage including reforestation and sequestration in agricultural soils via ‘zero-till’ methods or via the genetic modification of cultivars to enhance lignin content[6]. Is it geoengineering? Enhancement of terrestrial sinks has been seen as green and low-tech in sharp contrast with geoengineering. The idea has garnered wide support in industry and among environmental organizations. Yet, if implemented at the scale required to capture a significant fraction of emissions, terrestrial sequestration would resemble planetaryscale environmental engineering and may well entail high-tech methods such as genetic modification of crops. The divergent treatment of terrestrial andoceanic sinks illustrates the inconsistencies that pervade discussion of planetary engineering.

Sequestering CO2 Concept.

We may use fossil energy without emissions of CO_2 by first capturing the carbon content of fossil fuels while generating carbon-free energy products such as electricity and hydrogen and then sequestering the resulting CO_2 in geological formations or in the ocean[7]. Is it geoengineering? The term geoengineering was coined in the 1970s to describe the injection of power-plant CO_2 into the deep ocean. Despite this etymology it is unclear whether capture and sequestration is rightly classified as geoengineering. It is certainly an end-of-pipe technical fix, but(arguably) injection into geological reservoirs resembles conventional pollution-mitigation technologies more closely than it resembles geoengineering, because it limits emission of CO_2 to the biosphere rather than compensating for emissions after they occur. Put simply: if geological sequestration is end-of-pipe then biological sequestration is beyond-the-pipe.

Commentary

The post-war growth of the earth sciences has been fuelled, in part, by a drive to quantify environmental insults in order to support arguments for their reduction. Yet paradoxically the knowledge gained is increasingly granting us leverage that *may be used to deliberately engineer environmental processes at planetary scale.* *The manipulation of solar flux using stratospheric scatterers is perhaps the best example of this leverage:* we could reduce solar input by several per cent — probably sufficient to initiate an ice age — at an annual cost of less than 0.01% of global economic output 1,4. As remedies for the CO2–climate problem, all proposed geoengineering schemes have serious flaws. Nevertheless, I judge it likely that this century will see serious debate about — and perhaps implementation of — deliberate planetary-scale engineering.

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Cloud seeding
Greening
deserts
Genetically
engineered crops
Grow trees
Giant reflectors
in orbit
Aerosols in
stratosphere

Pump liquid CO_2
to deep sea
Iron fertilization of sea
Chemicals
to save
ozone
Pump liquid CO_2
into rocks
Schematic representation of various climate-engineering proposals (courtesy B. Matthews).
Box 1 Geoengineering