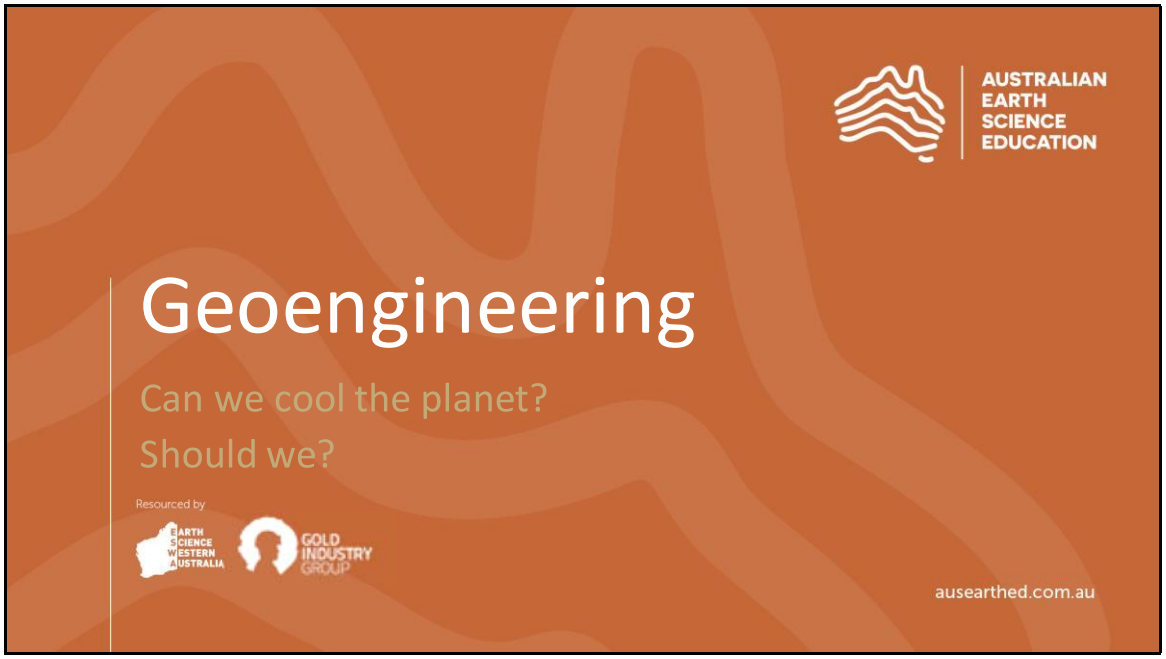

The first question is easily answered – yes, we can cool the planet.
Whether we should or not is the key question.

What is geoengineering?

Large-scale intervention in the climate system of Earth

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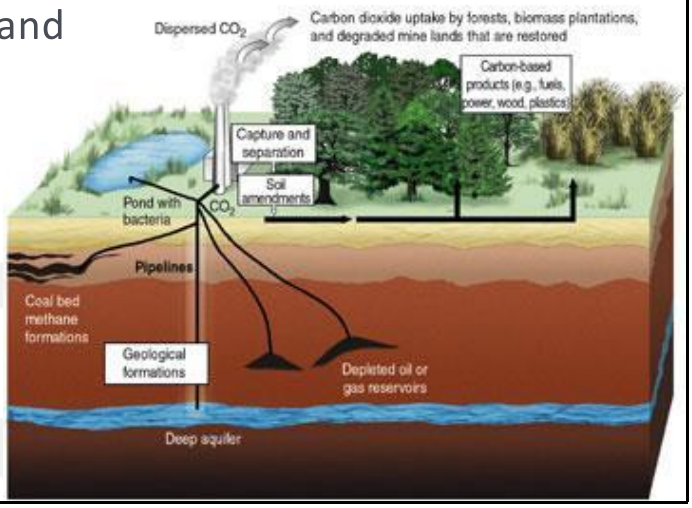
The idea of changing the climate initially began in the Cold War when scientists carried out extensive research into controlling the weather.
See Cool Australia for more background on this:
https://www.coolaustralia.org/geoengineering-secondary/

Two types of geoengineering

- Carbon capture and storage
- Solar geoengineering



Carbon sequestration (LJ Hardin & J Payne 2009, public domain)

Carbon capture and storage is exactly what it sounds like – removing carbon dioxide from the atmosphere and locking it up in stable reservoirs. This is widely accepted as a good thing. The diagram shows various options for carbon sequestration in products (wood), water and geological formations.

Solar geoengineering is increasing the reflection so that less solar radiation (especially infrared) reaches Earth. This is the controversial branch of geoengineering.

Carbon capture options: Reforestation

Idea: Plant trees to combat climate change

Scientific Basis: Trees remove carbon dioxide and store it for medium term in wood

Problems: Huge effort that could take a thousand years, slow to work, people may cut down the trees, trees may increase sunlight absorption in some areas

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This is a simple solution to many of the world's problems. Trees absorb carbon dioxide and lock it up for many years in wood. They also provide habitat and food for animals. It is a winning combination.

However, where could we plant trees? Scientists figured out where to plant trees in areas not immediately needed for humans and published this research in the journal Science. (https://science.sciencemag.org/content/365/6448/76)
An increase in forested area by 25% would store 25% of the current atmospheric carbon dioxide.

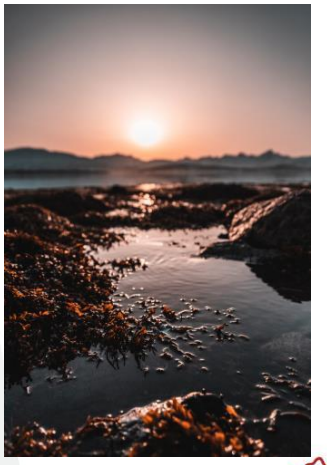
The recommended level of reforestation is 1-2 billion hectares. This would take 1000-2000 years to plant. Trees take 100 years to mature, then must be harvested for use and replanted. People may not wait for trees to reach maturity and may cut them down for fuel or to create agricultural areas. In polar regions, trees may decrease the natural reflection from snow-covered landscapes, thus increasing heat absorption.

Carbon capture options: Fertilise the oceans

Idea: Fertilise the oceans with iron

Scientific Basis: Iron is a limiting micronutrient for algal growth

Problems: Limited evidence of long-term storage, may cause blooms of toxic algae, effective range is narrow



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The idea of fertilising the oceans with iron was first proposed in 1990, when an oceanographer noted that iron-rich dust from land played a role in the last ice age by fertilising the ocean. The oceans are generally iron-poor and this limits algal growth.

Thirteen large experiments have shown increased algal growth with iron fertilisation, but only two featured long term storage. In order for fertilisation to be effective at changing climate, the carbon must be locked up in the deep ocean.

Many scientists are concerned that fertilising the oceans could cause blooms of toxic algae. In addition, research from MIT suggests that the effective range for iron is narrow and that iron fertilisation may not work on a global scale.

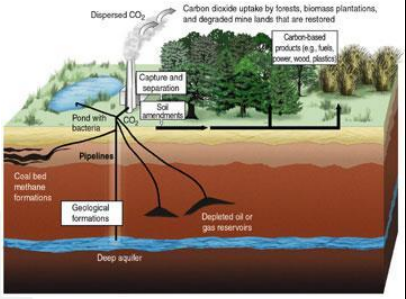
For more information: http://news.mit.edu/2020/oceans-iron-not-impact-climate-change-0217 or https://www.smithsonianmag.com/science-nature/complicated-role-iron-ocean-health-and-climate-change-180973893/

Carbon capture options: Technologies

Idea: Use technologies that can capture carbon and store it

Scientific Basis: A variety of technologies have been trialled

Problems: Technologies trialled are expensive and limited in their application



Carbon sequestration
(LJ Hardin & J Payne 2009, public domain)
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Governments planning for the future talk about carbon capture and storage (or sequestration) as if it can be done easily. There are a variety of options that include storing carbon dioxide in solution in saline aquifers, capturing carbon from the air via chemical reactions, using minerals that absorb carbon dioxide. All of these technologies pump the carbon into underground storage reservoirs.

Although it has been stated that we can use coal and combine it with carbon capture, this has not been achieved on a commercial scale. The technologies are still limited in scale and the long-term stability of underground storage is questioned by some researchers. Carbon sequestered in minerals will be more stable than that dissolved in aquifers.

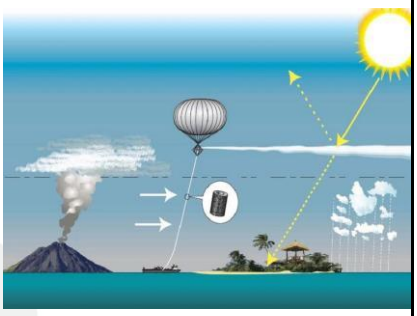
Read more from https://www.washingtonpost.com/news/theworldpost/wp/2018/05/31/carbon-capture/ or https://www.vox.com/energy-and-environment/2019/9/4/20829431/climate-change-carbon-capture-utilization-sequestration-ccu-ccs

Solar geoengineering options: Sulfur aerosols

Idea: Use stratospheric sulfur aerosols to reflect sunlight

Scientific Basis: Happens naturally after volcanic eruptions when aerosols reflect sunlight

Problems: Lasts only a couple of years; leads to acid rain, ozone destruction, drought and famine



SPICE project (Hughhunt 2011, Creative Commons)

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The simplest solar geoengineering option is to inject sulfur aerosols into the atmosphere. Any country with advanced aircraft could implement this solution quickly. We know it would cool the planet, because cooling happens after large, explosive volcanic eruptions (like Mt Pinatubo or Tambora) that cool the planet for a couple of years.

Unfortunately, reflecting sunlight comes at a cost. Primary production (photosynthesis) is reduced, sulfur aerosols damage the ozone layer and are eventually washed out of the atmosphere in acid rain. Research published in Nature Climate Change shows that aerosols in the Northern Hemisphere cause drought in the Southern Hemisphere.
http://empslocal.ex.ac.uk/people/staff/dbs202/publications/2013/haywood_nature_cc_paper.pdf

A group at Harvard has proposed using calcium carbonate aerosols. This avoids the health and ozone damage, but only one small experiment has been completed.
https://news.harvard.edu/gazette/story/2019/09/harvard-groups-research-planet-cooling-aerosols/

Solar geoengineering options: Cloud brightening

Idea: Use ships to spray salt water into the air and brighten clouds (can target specific areas)

Scientific Basis: Salt particles cause water to condense, making larger, brighter clouds

Problems: Could have effects far from the areas sprayed, unknown efficacy

Clouds from when water condenses around tiny particles of dust, salt or bacteria. Spraying salt water from the oceans into the air would cause thickening and brightening of clouds. This has been proposed as a way to cool and/or protect specific areas like the polar regions and/or coral reefs.

Unfortunately, there is no reasonable modelling of the impact this might have upon ocean circulation, weather patterns and local biology. Cloud whitening may lead to more variation in climate on top of the current increased variation due to the enhanced greenhouse effect. Ships would need to be powered by solar energy and these have never been built.

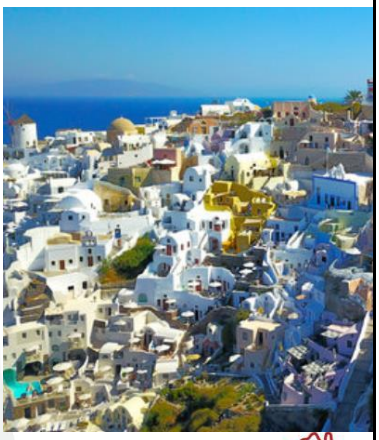
See https://www.carbonbrief.org/explainer-six-ideas-to-limit-global-warming-with-solar-geoengineering#cloudbright

Solar geoengineering options: White buildings and light crops

Idea: Increase albedo of buildings and crops

Scientific Basis: Light colours reflect more sunlight

Problems: Unlikely to make a large difference, crops may not be as productive as normal varieties



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Albedo is the amount of light reflected by a surface. White buildings and roofs reflect more sunlight than dark ones. Lighter-coloured crops or those with shiny leaves could also reflect more sunlight.

Unfortunately, the amount of change from increasing albedo is very small. It may be beneficial for reducing heat waves in cities. Many hot countries (i.e. Mediterranean areas) already reduce local heat islands by using light colours in building materials.

High albedo crops have not been developed and there are likely to be trade-offs between plant productivity and albedo. With an increasing world population in need of food, the likely choice will be in favour of productivity.

See https://www.carbonbrief.org/explainer-six-ideas-to-limit-global-warming-with-solar-geoengineering#cloudbright

Why we should us geoengineering

Warming is accelerating and Earth may be nearing a tipping point to runaway warming. Solar geoengineering can buy time to develop effective carbon capture solutions and reduce emissions.

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Content Slide

Why we should not use geoengineering

Geoengineering is a short-term solution that does not address the problem of carbon emissions. Proposed methods are often ineffective or dangerous. Rich countries can afford to mitigate the effects of geoengineering, but poor countries may be badly affected.

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