Engineering our climate

Fact sheet: *What is plan B?*

What is geo-engineering?

Geo-engineering offers solutions that directly modify the Earth's environment and climate to help ease the effects of global warming. It includes a range of techniques that deliberately manipulate the Earth's climate to counteract the potential impacts of global warming from greenhouse gas emissions. The National Academy of Sciences defined geo-engineering as "options that would involve large-scale engineering of our environment in order to combat or counteract the effects of changes in atmospheric chemistry."

Geo-engineering is not a new concept to scientists but it has come to light in the debate on solutions to global warming and the consequences of climate change.

Plan A is to significantly reduce greenhouse gas emissions for a long term solution, however, globally progress has been slow and at current rates of emissions global temperatures could rise 5.5 degrees Celsius by 2100 (this is currently considered to be the worst case scenario, although some scientists believe we are already on course for this).

Plan B is geo-engineering. Many environmental scientists consider geo-engineering techniques to be a **viable addition** to reducing greenhouse emissions but **not a replacement solution**. Some regard geo-engineering to be 'a sticking plaster for the planet', only helping to fix the problem once it's occurred. They argue that the technologies will be used as an excuse for countries to continue to emit large volumes of greenhouse gases (ghg) instead of investing in the actual reduction of greenhouse gas emissions.

A report published by the Royal Society in September 2009 stated that many of the engineering proposals were 'technically possible', but most were in their very early stages, with many in conceptual stages. Some of the technologies were considered to be 'too risky' and could potentially be damaging environmentally, saying there were many "major uncertainties regarding its effectiveness, costs and environmental impacts". The report states the approaches could be effective, but it stresses that geo-engineering should not divert governments away from their efforts to reduce carbon emissions. The report's chair, John Shepherd of the University of Southampton, said that neither he nor the working group advocated geo-engineering. "Our opinions range from cautious consent to very serious scepticism about these ideas. It is not an alternative to emissions reductions and cannot provide an easy quick fix."

Whilst many of the schemes suggested seem very ambitious and possibly far fetched, the report did conclude that many of them potentially had merit, and research into them should be pursued.

It is important to remember that whilst many of these technologies may work in theory, their actual effectiveness will not be known until they are tried, yet the environmental consequences of building and trying them will also not be known until then.
The report's biggest recommendation is for further research to be carried out.

But the study does break new ground in attempting to rank the different contending technologies according to how effective they're likely to be, how much they're likely to cost, how safe they appear, and how quickly they could be deployed (see the effectiveness/affordability diagram from News Scientist)

It is important to reiterate to students that geo-engineering is not an alternative to emissions reduction, but are an accompanying strategy and the technologies may not be the fix to carbon dioxide removal from the atmosphere that many scientists hope they will be.
Professor Shepherd was keen to emphasise that although some of the technologies might have a role to play one day, today is not that day. He did say that 'unless the world community can do better at cutting emissions, we fear we will need additional techniques such as geo-engineering to avoid very dangerous climate change in the future."

Geo-engineering proposals include putting giant mirrors in space, pumping iron fillings into the ocean, erecting carbon dioxide scrubbers that would 'clean' the air and painting roofs white.
The projects can be divided into **two groups**:

1. Those that **remove carbon dioxide from the atmosphere** and store it somewhere (**carbon sequestration**) and
2. and **ones which manage the solar radiation coming in,** sunshade projects, which attempt to cool the planet by reflecting some of the radiation away (**solar radiation modification**)

The table below looks at 7 geo-engineering techniques and explains how they would work, their effectiveness and the possible consequences.

Geo-engineering technique	How they work	The positives	The negatives
1. Ocean fertilisation (ocean seeding, iron fertilisation) The addition of large quantities of iron or other nutrients to areas to the upper ocean.	The nutrients act as fertilisers, encouraging the growth of huge blooms of algae and phytoplankton. As these plants grow CO^2 is used up during photosynthesis, so reducing CO^2 in the air. When the blooms die the CO^2 will sink to the sea bed in the dead organic matter.	The small scale experiments carried out so far have been successful in proving the theory. Biological productivity increases which can benefit the marine food chain.	Many scientists question whether this process removes CO^2 permanently, believing it may circulate in the oceans and be released (unsure as to how deep the plankton would sink) The production of iron is energy intensive so could produce more CO^2 than it removes. Marine ecosystems have evolved a natural balance over millions of years and therefore the ability to cope with change is unknown. Long term ecological impacts, particularly on fragile ocean environments are unknown.
2. Artificial trees (carbon scrubbers) Machines that can capture CO^2 from the air and filter it out as air passes through them.	Artificial trees or 'carbon scrubbers' can trap CO^2 on absorbent plastic sheets called ion exchange membranes. The CO^2 can then be removed from the membranes and captured. Once captured it can be stored (See **CCS**). If the CO^2 is combined with sodium hydroxide, a liquid solution of sodium carbonate is produced which can be piped away. The CO^2 can then be recovered from this and stored.	It's estimated that each artificial tree could remove 90000 tonnes of CO^2 a year, equivalent to 20000 cars. The units being designed are a similar size to shipping containers, easy to transport & can be located where there are high CO^2 outputs, or near to **CCS** plants, so eliminating transport costs. It is hoped as the technologies advance & costs are reduced, structures similar to trees can be built for locations alongside roads etc. Currently the UK produces 556 mega tonnes of CO^2 per year and the 100,000 trees could absorb around 60% of that amount. A study by the Institute of Mechanical Engineers calculated that forests of artificial trees powered by renewable energy & located near depleted oil or gas fields, where the trapped CO^2 could be buried, would be thousands of times more efficient than planting trees over the same area (Guardian 27 Aug 2009). This process does remove CO^2	1 million trees would be needed to soak up the world's current emissions and the CO^2 would still need to be disposed of. It is uncertain whether technology would be efficient at huge scales required. Cost is approximately £15 000 per unit and the UK would need 100 000. Many scientists recommend this technology should be developed in conjunction with carbon storage infrastructure. Making each artificial tree would require energy and materials, although this would be a small amount compared to what it could capture.
3. Carbon Capture Storage (CCS) The trapping of CO^2 as it's emitted from point sources, such as power plants, transporting it to suitable storage sites	There are 3 stages in this process: 1. Capture – CO^2 is separated from other gases using separation technologies. 2. Transport – the CO^2 is transported via pipeline in a supercritical state (it behaves as both a liquid & gas) to a storage site 3. Storage – there are several	Currently there's much scientific research into this option as a viable possibility. Could reduce emissions directly at source so they do not enter the atmosphere. There's some political support for this option The captured CO^2 can be injected into existing depleted oil and gas reservoirs and other geological features	The process is very costly. There is some concern over longer term effects of CO^2 storage and whether there is any chance of the CO^2 'leaking' – scientists do say this is very low risk though if the appropriate sites are chosen At present this technology is fairly energy intensive.

and storing it underground.	possible options, the most popular at present is to inject it into depleted oil and gas reservoirs and other geological formations such as a sandstone layer underneath the North Sea.	A Norwegian company has been successfully doing this for several in the North Sea	
4. Sulphur screens (Stratospheric aerosols) The addition of sulphur particles to the upper atmosphere to reduce incoming solar radiation	A screen of shiny sulphur particles would be sprayed into the stratosphere by aircraft or balloons. These help to partially reflect some of the sun's radiation back into space, mimicking the natural process that occurs during volcanic eruptions.	The experiment has been done! Mount Pinatubo erupted in 1991, emitting 10 million tonnes of sulphur and average global temperatures fell by 0.6°C for two years. There is some support from scientists. This is relatively cheap compared to other techniques. The timescale to undertake this is fairly short.	The problem of increasing CO^2 emissions is not addressed and the subsequent effects this creates including ocean acidification. Possible side effects include changes to the global water cycle and rainfall – possible droughts and the knock-on effects this may have on ecosystems. Increasing amounts of sulphur in the atmosphere can cause acid rain, with devastating effects on plants and animals. Sulphur in the lower atmosphere can result in an increase in respiratory diseases. Whilst it may be relatively easy to do, it would require continual effort as the chemicals gradually fall back to Earth.
5. Increasing reflectivity (modifying the albedo) Using reflective materials on rooftops and pavements or painting them white or paler colours.	The more reflective a surface is the greater the albedo, so greater the reflection rather than absorption of solar radiation. Research is being carried out into increasing the reflectivity of other land surfaces, including agricultural areas, deserts and ice caps, for example scientists have 'wrapped up' glaciers in reflective blankets to try and reduce melting.	This could delay the global warming and the consequences of climate change. California has adopted this approach; all new and redeveloped residential & commercial structures with flat & sloping roofs must have heat-reflecting roofing. This technique is relatively cheap compared to others. The timescale for introducing this is quite short (especially for painting roofs).	The problem of increasing CO^2 emissions is not addressed and the subsequent effects this creates including ocean acidification.
6. Increasing cloud reflectivity A fleet of specially designed wind-powered ships would spray sea water particles into the atmosphere in order to increase the cloud density,	When the seawater in the atmosphere evaporates salt crystals are left behind. These act as nuclei for water droplets to condense on and form clouds. A greater concentration of nuclei increases the density of the clouds and dense clouds reflect more than thin clouds, so the earth's temperature would decrease.	Sea water is readily available in the oceans! It's estimated that 1.4 billion tonnes of sea water would need to be converted annually needed annually to increase the albedo enough to compensate for global warming. Could help buy time for adjusting to a low carbon society. The ships could be turned off at any time if there are damaging consequences.	This technique does not reduce the CO^2 in the atmosphere, so does not address problems such as ocean acidification. Ships will need to be in constant use for this to be effective. Critics warn that although such schemes might lower temperatures swiftly, they would have to be maintained for long periods and the side-effects on local climate patterns of wind and rain are unknown. Dr Vicky Pope, head of climate change advice at the Met Office, said: "Anything that alters the climate

so increase their reflectivity.			in a different way from reducing carbon has inherent dangers because we don't understand the climate well enough." (Times). The technology is not yet developed.
7. Space mirrors (space sunshade) A giant sunshade in space could block the sun.	More likely to be a collection of millions or even trillions of small mirrors rather than a giant orbiting parasol that would reflect the incoming solar raditation away from earth.	The solar rays that are reflected would compensate for the increase in temperatures created by global warming.	Very expensive. Many additional rockets would need to be built to enble all the launches, which could cause problems for the ozone layer and create additional emissions. The reduction in solar radiation could have a major impact on the earth's processes.

An excellent **graphic** illustrating many of these proposals can be found on the Financial Times pages.

It is evident that geo-engineering presents many challenges. Much research continues into the scientific theory to find the answers that are needed to the many questions posed by geo-engineering before it gets the go-ahead. But who will it get the go-ahead from? Scientists, national governments, international bodies, non-governmental organisations, the public – these are just a few of the groups who will have something to say about it.

- Who will pay for the scientific research and the new technologies needed?
- Will the poor be excluded from these options even though they are most likely to suffer from the consequences of climate change?
- Is it right to interfere with natural processes despite the fact that anthropogenic activity is largely to blame?
- Are the consequences of doing nothing greater than the possible impacts of geo-engineering?
- Should we be using unsustainable techniques?
- Who and where would benefit from such techniques and what gives them the right to decide because their actions might have disastrous consequences elsewhere?
- Are the dangers associated with geo-engineering too great?
- Do the consequences of geo-engineering outweigh the threat that continued global warming poses?

These are just a few of the many questions that are raised by the concept of geo-engineering that promote discussion.

Key terms

Albedo: the amount of incoming solar radiation (insolation) that is reflected by the Earth's surface and the atmosphere. The planetary average for the albedo is 32% of insolation, but this varies from place to place. Dark coloured areas of the world, such as coniferous forests, reflect small amounts of insolation (10%) whereas light-coloured areas such as deserts reflect larger amounts (35%). Fresh snow and ice have very high albedos, up to 90%. The less reflection there is means the greater the absorption, so dark areas absorb more heat so making the Earth's surface warmer.

Anthropogenic activity**:** human activity usually used to describe environmental effects that humans have on an environment. Man-made CO^2 is considered responsible for global warming as a greenhouse gas.