# Air Capture (CDR)

- 'Artificial trees' remove carbon dioxide from the air
- Air passes through chemical solutions or compounds that absorb and collects $CO_2$
- The trapped carbon molecules are then removed, transported and stored safely
- Cost - relatively expensive (technology not yet well-developed).
- The process of separating the $CO_2$ from the collectors requires energy and chemical materials. There would also be costs of transporting and storing the large volumes of carbon dioxide (hundreds of millions of tonnes for the UK, if the process is to counteract current emissions).

## What would they look like?

- Possible designs include 50-300 foot tall, 8ft wide steel goalposts or shipping container-size to small one for each household.
- Placed in the desert, or in North sea and powered by the energy from wind farms.
- They could be put up individually or in 'forests' of millions of 'trees, clustered around sites where $CO_2$ could be safely stored.

# What are the issues?

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## Advantages

- Potentially could remove thousands of times more carbon dioxide than a real tree.
- Can be placed anywhere, even underground, and would not require international agreement
- Safe and shouldn't have any bad side effects (although $CO_2$ storage has risks)
- Would operate 24 hours a day but could be switched off easily if something went wrong
- Easy to measure the amount of carbon captured

## Disadvantages

- A lot of infrastructure is required for construction, maintenance and removal, with energy needed to drive the process. Could be more efficient to use that energy to meet primary needs, and not to release the $CO_2$ in the first place.
- They would be slow to reduce global temperatures
- The capture devices may be an eyesore and could take up land space
- There aren't that many places to store $CO_2$ underground

# Iron Fertilisation (CDR)

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- Adding nutrients e.g. iron to some areas of the ocean to promote ‘blooms’ of algae
- As the algae grow they soak up carbon dioxide from the atmosphere
- When they die, they sink out of the upper ocean, taking the carbon with them potentially for hundreds of years.
- In the last 15 years, 12 test studies have been carried out. Experiments with iron fertilisation have already been carried out in iron-starved ocean regions, the Equatorial Pacific, North Pacific and Southern Ocean.

# What are the issues?

Experiment Earth? Public Dialogue on Geoengineering

## Advantages

- Initial small scale effectiveness has been demonstrated using iron
- Process itself not too expensive
- Could help increase marine productivity as zooplankton and fish would feed off the algae

## Disadvantages

- May not be that effective in long term, since most $CO_2$ taken up by algae is returned to the atmosphere within a year. Expensive and difficult to quantify how much carbon has been 'permanently' removed
- Unknown side effects on sea life
- Effects on marine ecosystems not necessarily beneficial; could result in release of other greenhouse gases
- Legal framework under development; research currently restricted under international law
- Results of early tests suggest it may not be as effective as hoped.

# Liming the Ocean (CDR)

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- $CO_2$ in the atmosphere dissolves in the sea making it more acidic which can harm marine life (particularly coral reefs.
- An alkali, in the form of lime made from limestone rock, would be added to the oceans to make them less acidic.
- The water being more alkaline would mean it would absorb more $CO_2$ from the air, reducing global warming.

# What are the issues?

Experiment Earth? Public Dialogue on Geoengineering

## Advantages

- Making the water less acidic would benefit marine life and help save coral reefs.
- Will remove some $CO_2$ from atmosphere.

## Disadvantages

- Expensive and uses a lot of energy - need to pay for mining the limestone, processing and transporting it, all of which also produce $CO_2$.
- Initial release of $CO_2$ when limestone converted to lime.
- Expensive and difficult to verify how much carbon has been 'permanently' removed.
- Slow to reduce global temperatures.
- May have unintended effects on ocean ecosystems.
- Would require international agreement and substantial infrastructure building.
- Limestone quarries would be an eyesore.

# Biochar (CDR)

- Vegetation removes carbon from the atmosphere during photosynthesis. When it dies it decomposes releasing its carbon back into the atmosphere
- Instead the vegetation is heated and starved of oxygen to lock the carbon into biochar (finely grained charcoal).
- The biochar is then buried & it can store away carbon for thousands of years

# What are the issues?

Experiment Earth? Public Dialogue on Geoengineering

## Advantages

- Lots of waste materials can make biochar; wood, leaves, food waste, straw or manure.
- Adding biochar to soil can improve agricultural productivity.
- When making biochar, biofuels and bio oils are produced which can be used as a renewable fuel source.
- Relatively cheap.
- A natural process so not much risk of unintended side effects.
- Addresses the cause of climate change directly.
- Farmers could make a profit from selling their Biochar.
- Everyone could do it and it can be implemented everywhere.

## Disadvantages

- Will require additional energy consumption for transport, burying and processing.
- May disrupt growth, nutrient cycling and viability of the ecosystems involved.
- Doesn't make a massive difference to global temperatures but can be used on a small scale to remove some $CO_2$.
- May be conflicts over land use with for agriculture and growing crops for biofuels
- Not enough land available to carry out this process on sufficient scale (particularly since global population likely to double). Would compete with agriculture, timber production and growing crops for biofuels

# Afforestation (CDR)

Experiment Earth? Public Dialogue on Geoengineering

- Rainforests and temperate forests are being cut down to use the land for agriculture and grazing - increase in emissions of methane from cattle on the land
- This is contributing substantially to global carbon emissions because there are fewer trees to absorb $CO_2$: loss of tree biomass and soil carbon
- Planting more trees and managing the land use would help reverse this effect

# What are the issues?

Experiment Earth? Public Dialogue on Geoengineering

## Advantages

- Very cheap
- Addresses the cause of climate change directly
- Could be implemented in a very short timescale (but would need permission – who from?)
- Process understood so less risk of unwanted side effects
- Integrated land-use planning, as well as reducing carbon can have benefits for the economy, water regulation, biodiversity conservation and agriculture

## Disadvantages

- Not enough land available to carry out this process on sufficient scale (particularly since global population likely to double) to make a massive difference to global temperatures
- Political conflicts over land: would compete with agriculture and growing crops for biofuels
- Biodiversity may change which may be bad for some species

# White Roofs (SRM)

- Making surfaces more reflective means that less heat from sunlight is absorbed by the Earth's atmosphere and temperatures are lowered.
- It has therefore been suggested that painting surfaces of man-made structures such as buildings, roads and pavements white could lower temperatures
- Very expensive

# What are the issues?

Experiment Earth? Public Dialogue on Geoengineering

**Advantages:**

- Quick to implement
- Technically easy to do

**Disadvantages:**

- Global-scale effect insignificant
- Only effective if scaled up thousands of times (e.g. cover the Sahara desert)
- In temperate regions more heating would be required in winter
- Better to capture solar energy – to replace fossil fuels
- Does not solve the problem of ocean acidification

# Mirrors in Space (SRM)

Experiment Earth? Public Dialogue on Geoengineering

- Giant mirrors or reflective mesh could be put high up in space, acting as a sunshade to reflect sunlight away from the Earth and prevent it warming up.
- There could either be several large pieces of mirror kilometres wide, or trillions of smaller reflective discs only a few centimetres in size.

# What are the issues?

Experiment Earth? Public Dialogue on Geoengineering

## Advantages

- Would work immediately once implemented, so could be used in a climate emergency
- Would be effective, making a big change to global temperatures

## Disadvantages

- Relatively expensive
- Would take at least several decades to develop the technology and to put the reflectors into orbit
- May have an uneven cooling effect where the tropics get cooler but the polar regions get warmer
- Could have unpredictable and undesirable effects on weather systems
- May reduce plant production (crops and natural ecosystems)
- May not be easily reversible
- Fears over weaponisation
- Requires international agreement
- Does not solve the problem of ocean acidification

# Cloud Whitening (SRM)

Experiment Earth?
Public Dialogue on Geoengineering

- Some clouds cool the Earth by reflecting sunlight back into space
- Lots of small clouds reflect light better than fewer bigger clouds.
- By spraying small seawater droplets into the air over the sea, it is possible to increase the reflectivity and (possibly) longevity of existing clouds
- The seawater could be deployed using normal ships, radio controlled vessels or aeroplanes

- Best places are over sea on the west coast of North and South America and the west coast of Africa
- Take 2 years to build an experimental spray system and 2 years to carry out the experiment

# What are the issues?

Experiment Earth? Public Dialogue on Geoengineering

## Advantages

- Could start reducing temperatures in a short time period.
- Easy to turn off if there's a fault.
- Cloud formation occurs naturally so this enhances a natural process that is fairly well understood.
- Not too expensive.

## Disadvantages

- We don't know how expensive it is likely to be
- It may not be that effective at reducing temperatures.
- Effects may only last a few weeks so it would need to be carried out repeatedly which would cost money and take time
- It may have unwanted effects on the weather and sea-life, particularly in areas where cloud spraying occurs as it can cause a large local drop in temperatures
- If regional weather patterns are adversely disrupted, who pays compensation?
- Does not solve the problem of ocean acidification

# Sulphate Particles (SRM)

- Would mimic what happens when large volcanoes like Mount Pinatubo erupt, sending sulphates up into the air. This tends to happen every 10 to 30 years. The eruption of Mt Pinatubo reduced global temperatures by 0.5$^{o}$C for two years (1991-1993)
- Sulphates scatter the sun's rays back into space, preventing them from reaching Earth and so cooling the earth
- Military planes or hot air balloons would disperse sulphates.
- Computer modelling has been carried out
- Surprisingly, the amount of sulphate involved is quite modest (less than 5% of the amount already emitted by industry) and so would not significantly add to acid rain.

# What are the issues?

Experiment Earth? Public Dialogue on Geoengineering

## Advantages

- Effective at lowering temperatures. Injecting sulphate particles every one to four years would have the same effect as a volcanic eruption
- Works fast - could start lowering temperatures within a year
- Relatively inexpensive
- Computer models suggest that the sulphate layer would reduce temperatures
- Can be turned off quickly - in one to two years

## Disadvantages

- Requires constant input - If you suddenly stopped the world could get hotter very quickly
- Effects would only last a few years so have to be repeated which would cost more
- Uncertain side effects- may affect the climate/rainfall and lead to droughts
- Requires international agreement
- Could damage the ozone layer and high altitude clouds
- Does not solve the problem of ocean acidification

# Sources

**Information in this report came from:**


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If you would like more information about Climate Change visit: 1) Direct Gov at http://www.direct.gov.uk/en/Environmentandgreenerliving/Thewiderenvironment/Climatechange/DG_072901
2) NERC website http://www.nerc.ac.uk/
3) a joint statement on climate change prepared pre-Copenhagen by NERC, Royal Society and Met Office: http://www.nerc.ac.uk/press/releases/2009/29-climate.asp