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CLIMATE CHANGE & GEOENGINEERING

Long term impact of climate change & possible fixes

The current temperature rise projection is +2.6–2.9C above pre-industrial levels by 2100
We are accumulating green house gases by using resources at x4 the sustainable rate

The temperature could rise by 4-5C
Climate systems reaching Tipping Points can switch the climate to a new state

Excess CO_2 will naturally remain in the atmosphere for 1000's years
Removed very slowly by geological processes
Is geoengineering the answer?

Geoengineering is the deliberate large-scale intervention in the Earth's natural systems

The two principle geoengineering methods are:
Massive CO_2 removal from the atmosphere
Reflection of solar energy back into space

The risks of geo-engineering the climate systems are not well understood
More research needed

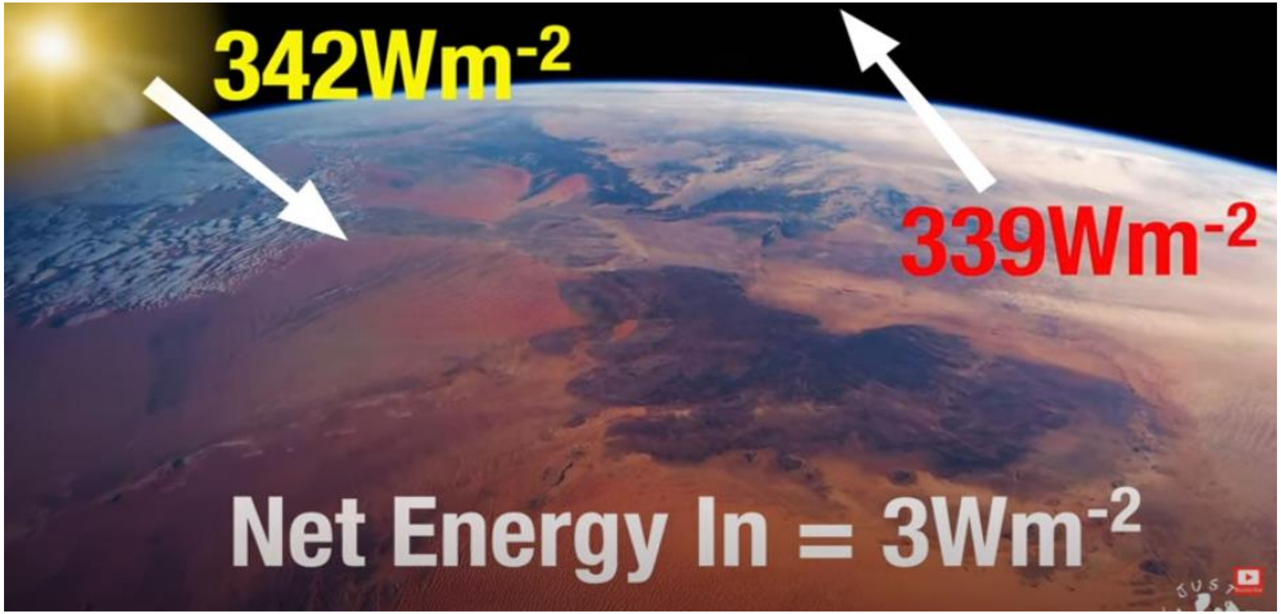
The challenge of geoengineering is scalability
Increase current methods by 20 – 100,000 times

Geoengineering research has expanded significantly over the past 5 years
The White House has began a five-year research programme into “climate interventions”

NET ENERGY FLOW?

The Earth receives average 342W/square metre from the sun

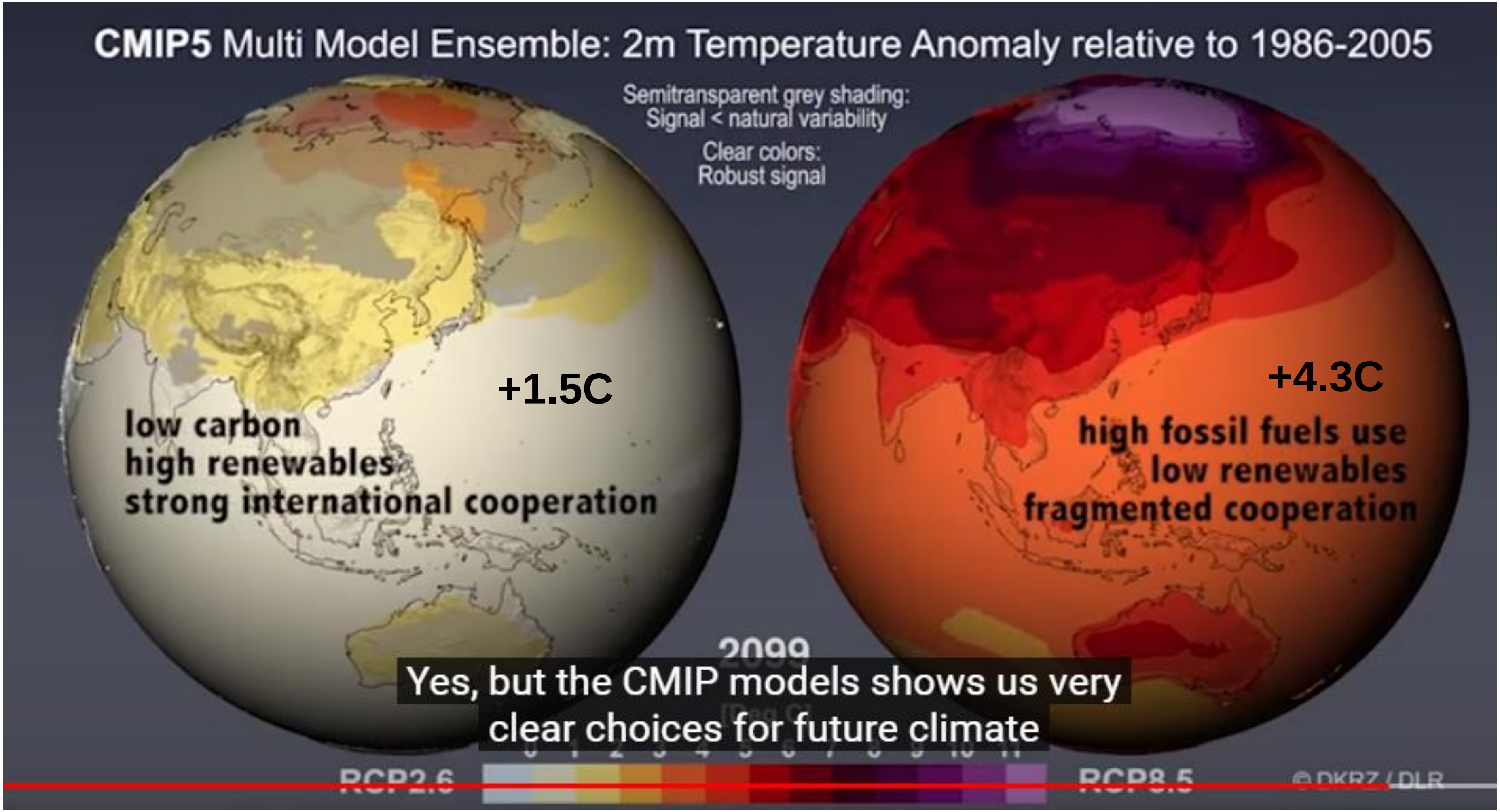
Increase in green house gases means the Earth re-radiates only 339W/square metre into space



A net gain of ~3W per square metre is producing global warming

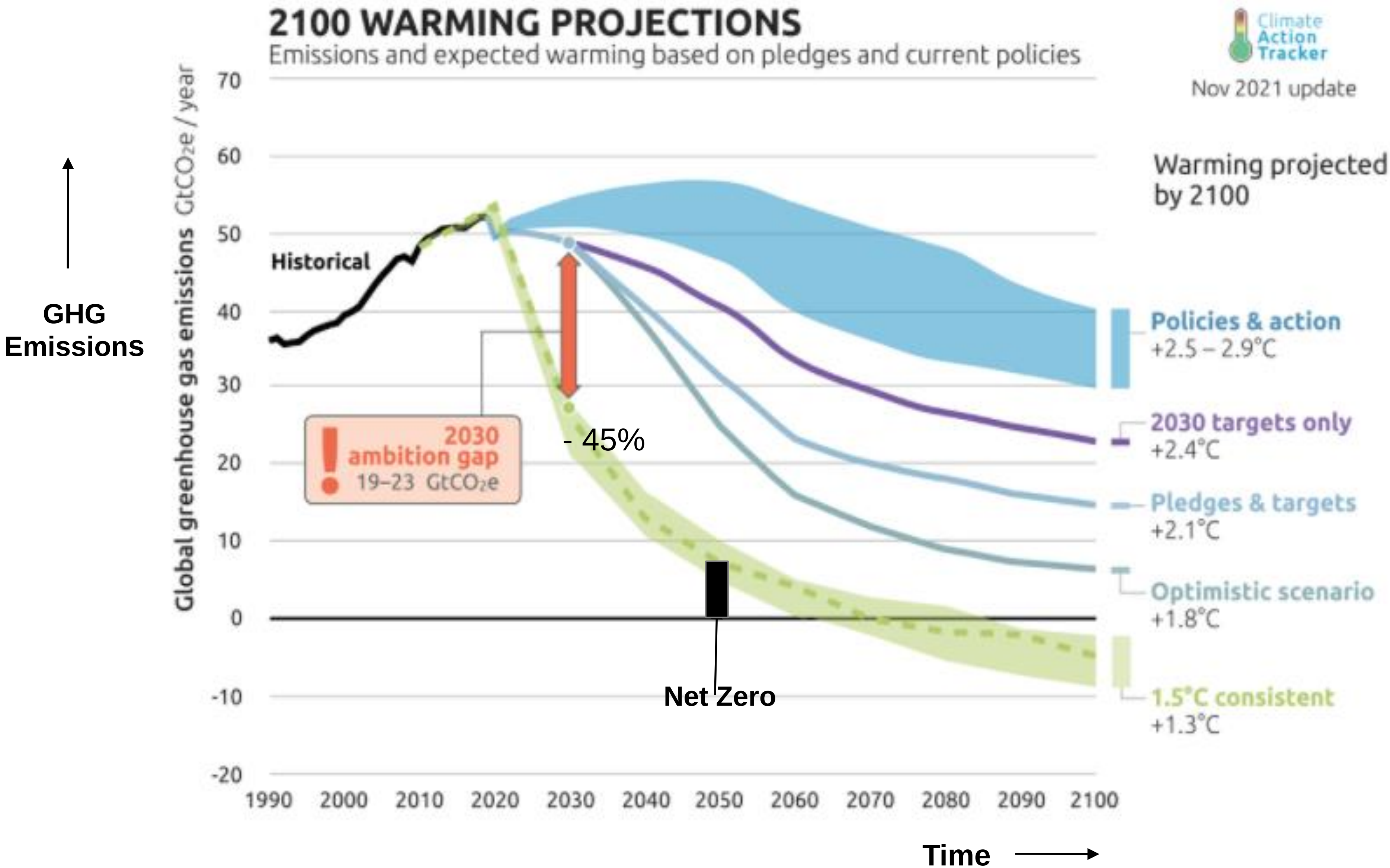
Can we eliminate the excess 3W/square metre by geoengineering methods?

COMPUTER MODEL TEMPERATURE RISE PREDICTIONS 2100



RCP= Representative Concentration Pathway

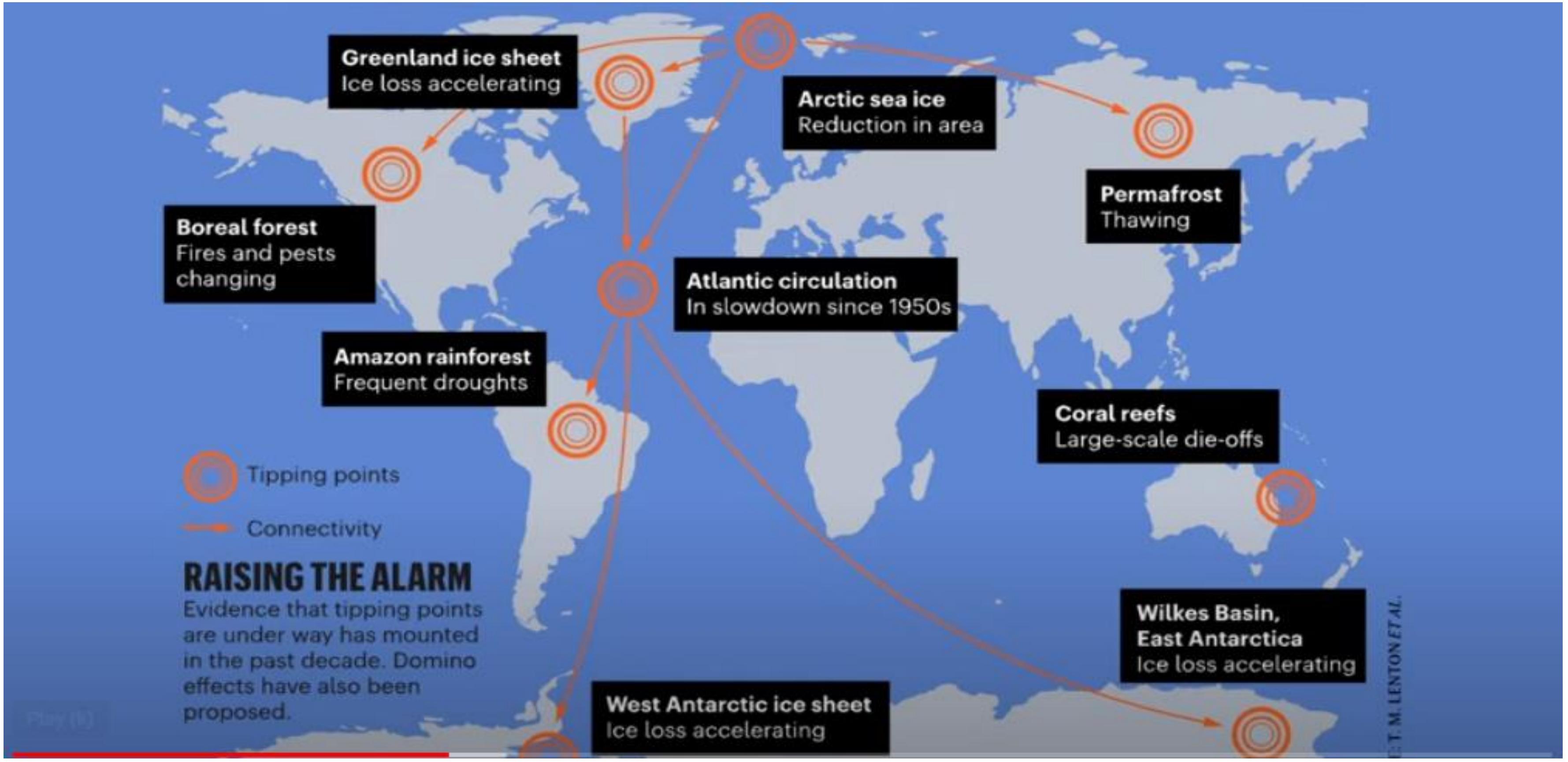
It's our choice



Projected global warming 2.6 – 2.9C by 2100

CLIMATE TIPPING POINTS

Accelerated irreversible warming due to positive feedback in climate systems



Domino effect where tipping points are triggered one after the other

Leading to accelerated climate change ~4-5C

CURRENT PREDICTION +3C EARTH

Parts of the Earth likely become uninhabitable due to heat & water scarcity
Increase from 0.8% to 18%

Desertification, extreme weather, water shortages, heat deaths...

What about world food production?

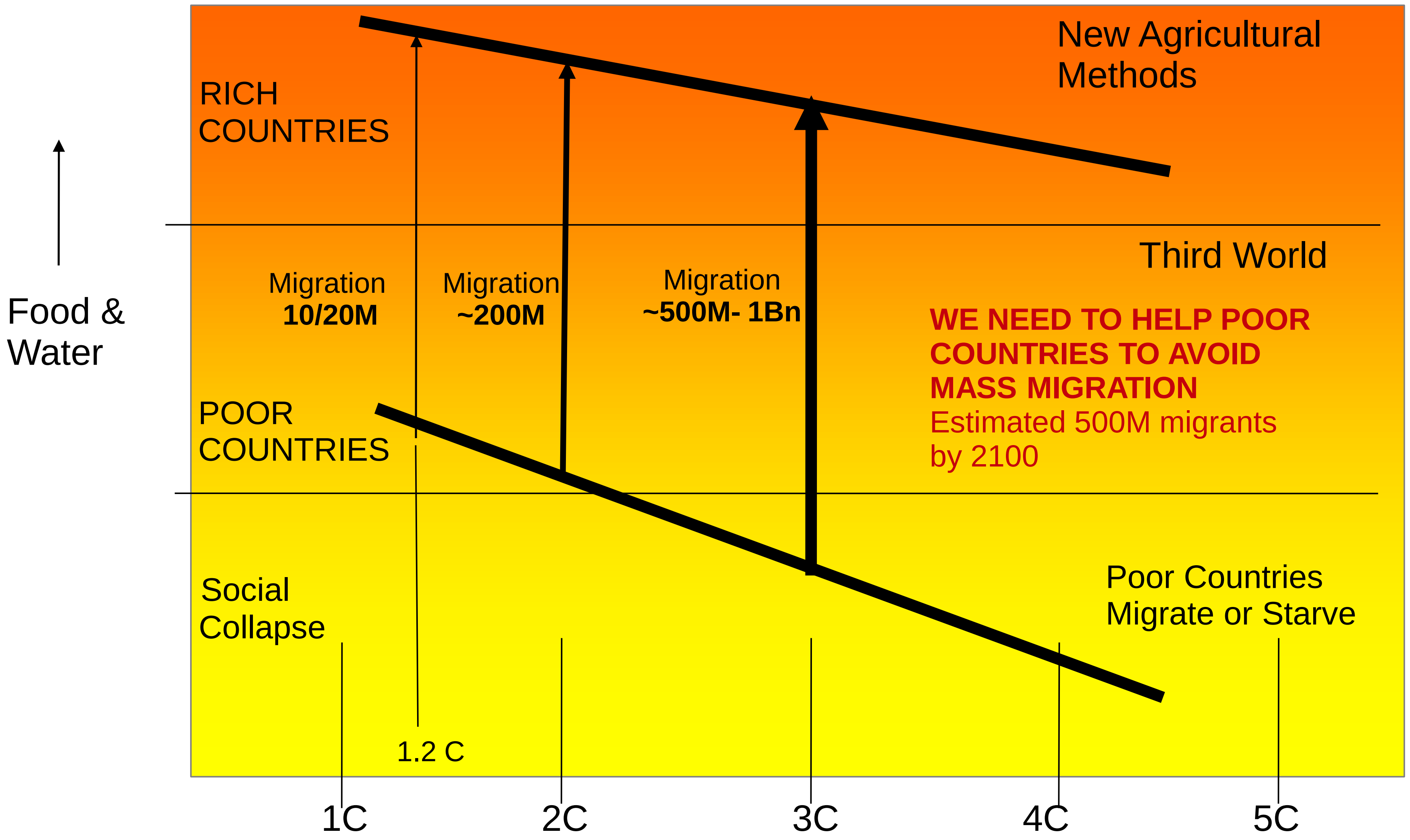
What about sea level rise?

What about mass migration from equatorial regions?

Coastal cities?

MASS MIGRATION FROM POOR COUNTRIES

Predicted 2.6 - 2.9C temperature rise by 2100



IMPACT OF SEA LEVEL RISE IN UK ON A +3C WORLD

TODAY

Increasing pressure on coastal defences

+150 Years

Melting of Greenland & Western Antarctic

13 metre sea level rise

Pressure on coastal towns & cities

+500 Years

Melting of all sea ice including Eastern Antarctic

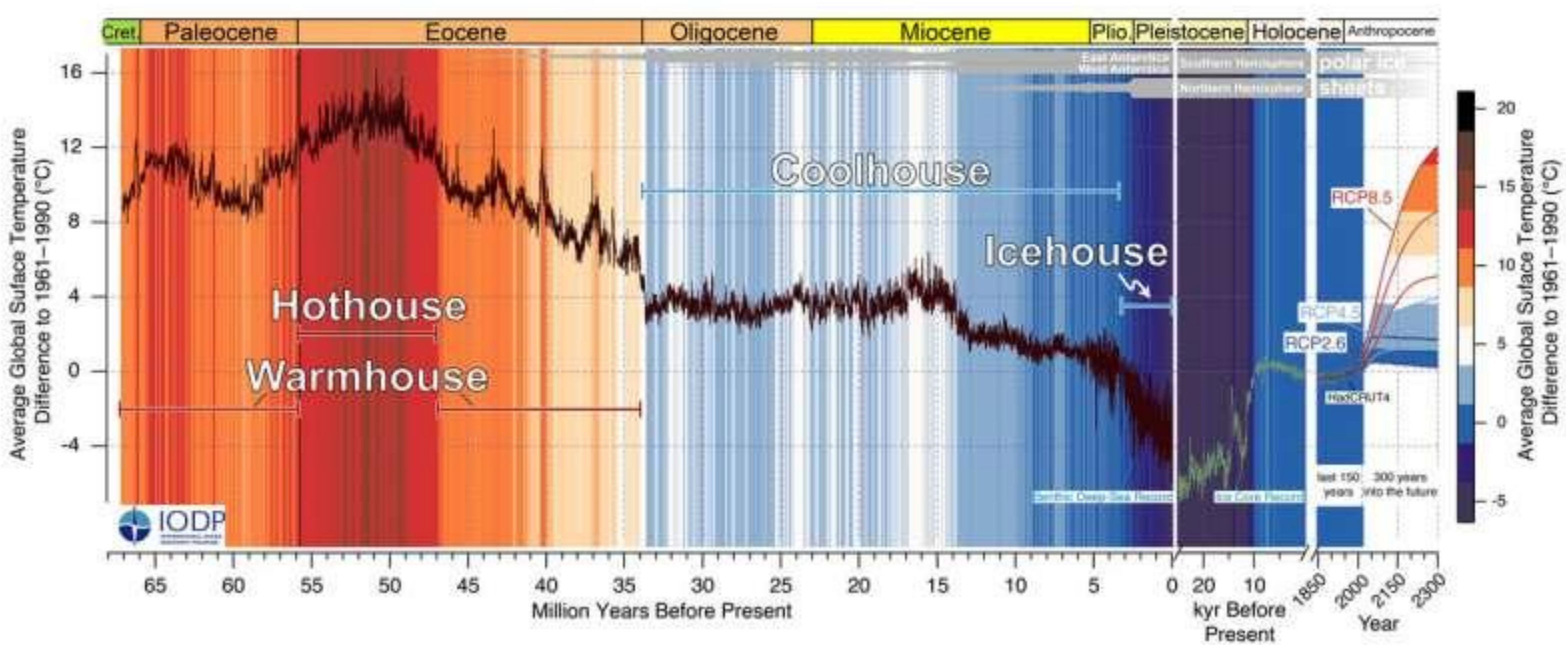
80 metre sea level rise

Major relocation of population

CLIMATE STATES

Historical records indicate 4 distinctive climate states Hot House, Warm House, <u>Coolhouse</u> & Icehouse Earth

Driven by volcanic activity, sequestration of CO_2 by rocks, sea & plants



These climate states can persist for millions of years

What will happen next?

What can we do about it?

GEOENGINEERING SOLUTIONS

Geoengineering is the deliberate large-scale intervention in the Earth's natural systems

The two principle geoengineering methods are:
Massive CO_2 removal from the atmosphere
Reflection of solar energy back into space

How effective are Geoengineering Solutions to climate change?

How long will they take to implement?

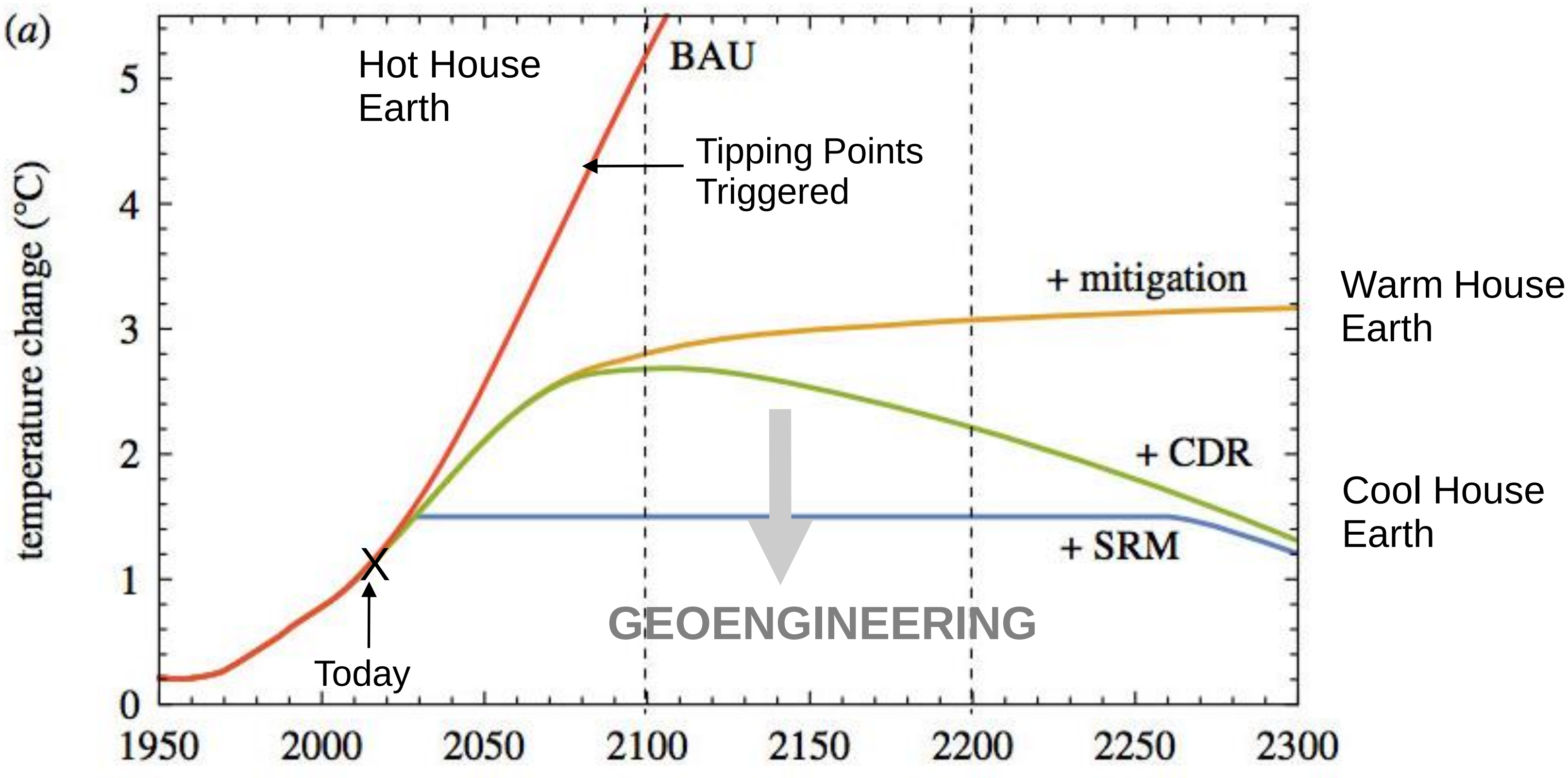
IMPACT OF GEOENGINEERING SOLUTIONS

BAU = Do Nothing

Mitigation = Limit CO2 Emissions

CDR= Carbon Dioxide Removal

SRM= Solar Radiation Management

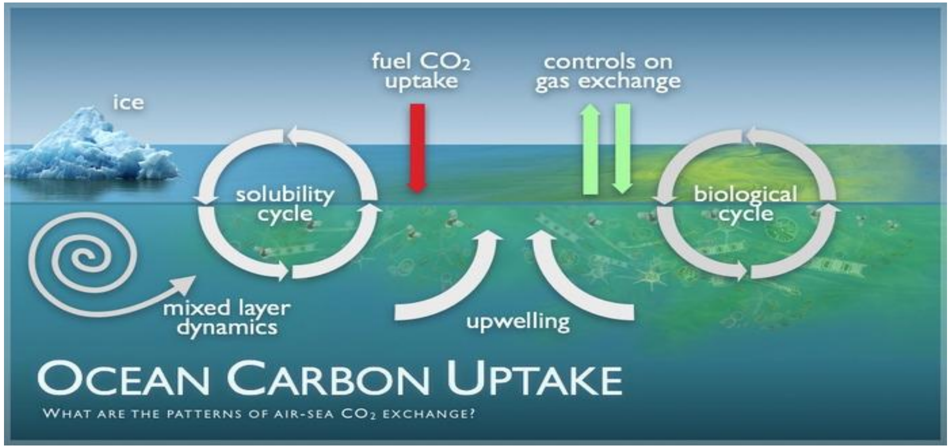


Geoengineering uses both CDR & SRM

The issue is scalability

GEOENGINEERING BY CO_2 REMOVAL (CDR)

OCEAN CARBON UPTAKE



Global emissions CO2 ~35 billion tonnes per year

The ocean acts as a “carbon sink” absorbing ~30% excess CO2 emissions
The ocean dissolves <u>limited excess CO2</u> but maintains its alkalinity to support life through natural biological & solubility Cycles

Ocean stores x50 carbon than the atmosphere and x20 more than land

<u>Hence most CO2 will remain in the atmosphere for thousands of years</u>

CARBON DIOXIDE REMOVAL (CDR)

CDR not the same as CCS (which removes CO_2 at source)

CDR = Forests (99.9%) + DACCS, BECCS... (0.1%)

Forests: Scaled by x20
to be effective
Vulnerable to fires
& droughts

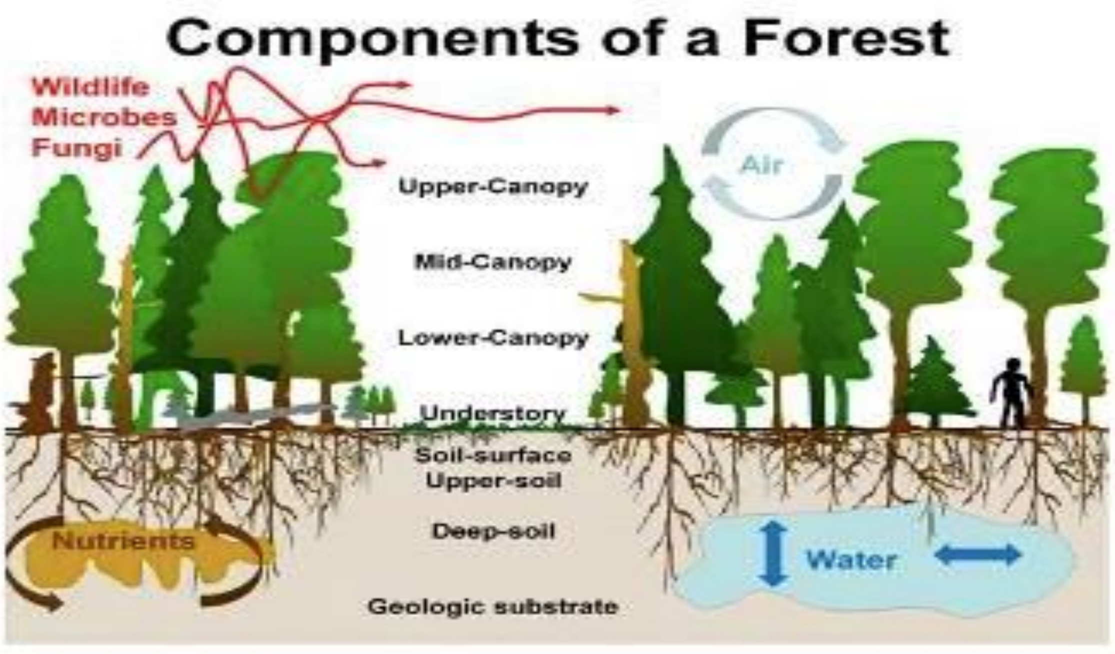
DACCS, BECCS: Scaled by
X20,000

DACCS = Direct Air Carbon Capture & Storage
BECCS = Bio Energy with Carbon Capture & Storage

FORESTS

Forests captures about 2 billion tonnes CO2 globally each year
35 billion tonnes emitted from all sources

CO2 absorption by photosynthesis in plants -> plant decay -> storage of carbon & moisture in soils → further plant growth

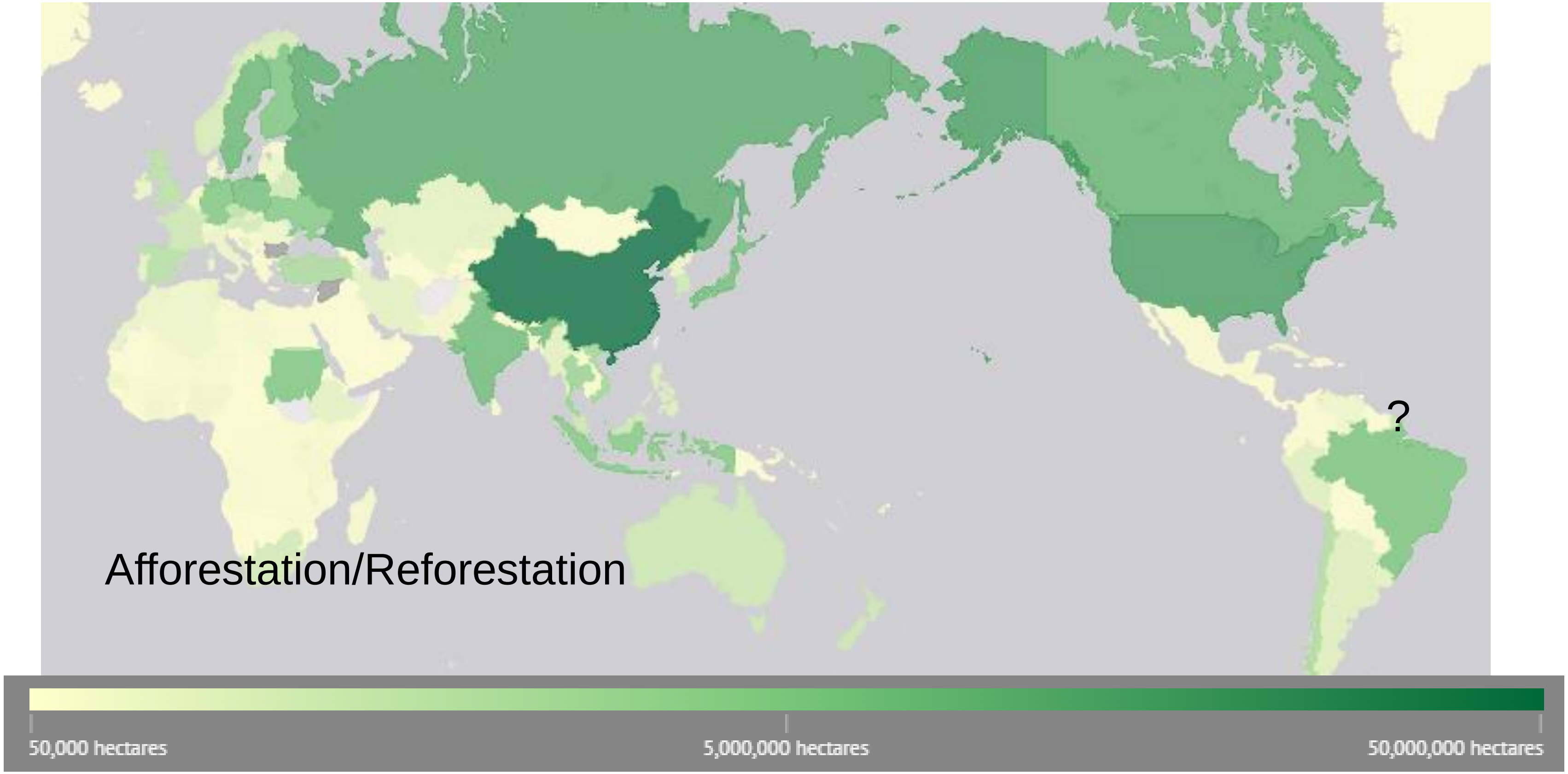


x20 existing forest coverage to absorb current emissions (size of US)

Forests are vulnerable to climate change (heat & drought)

FOREST ACTIVITY

x20 scaling needed!



FOREST PLANTING GUIDELINES

Use native trees adapted to the local environment

Avoid mono culture - plant a diverse range of trees & other plants for increased carbon sequestration & resilience to climate change

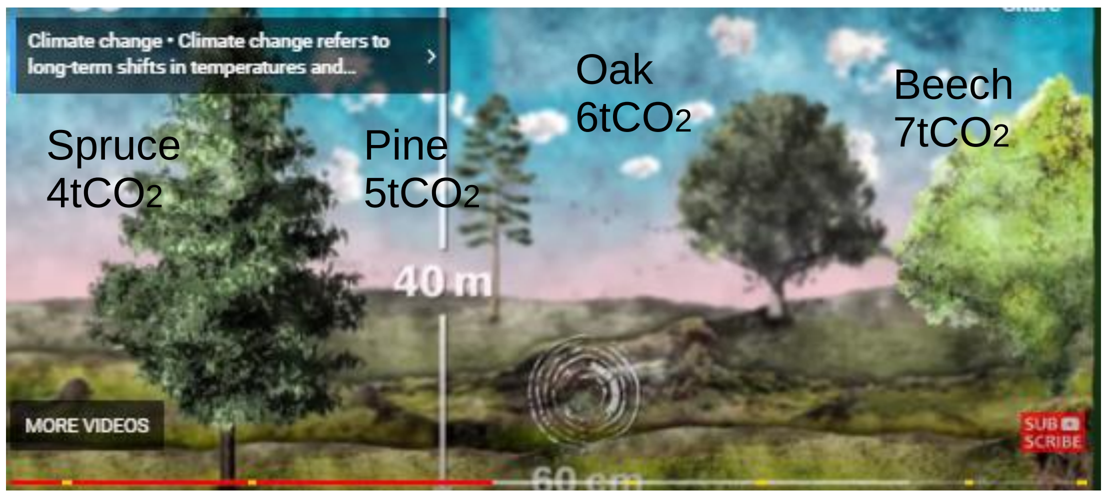
Mix of old & newer trees

Supplement rather than replace existing forest

Consider ecosystem restoration as a whole

Protect the rights of indigenous people

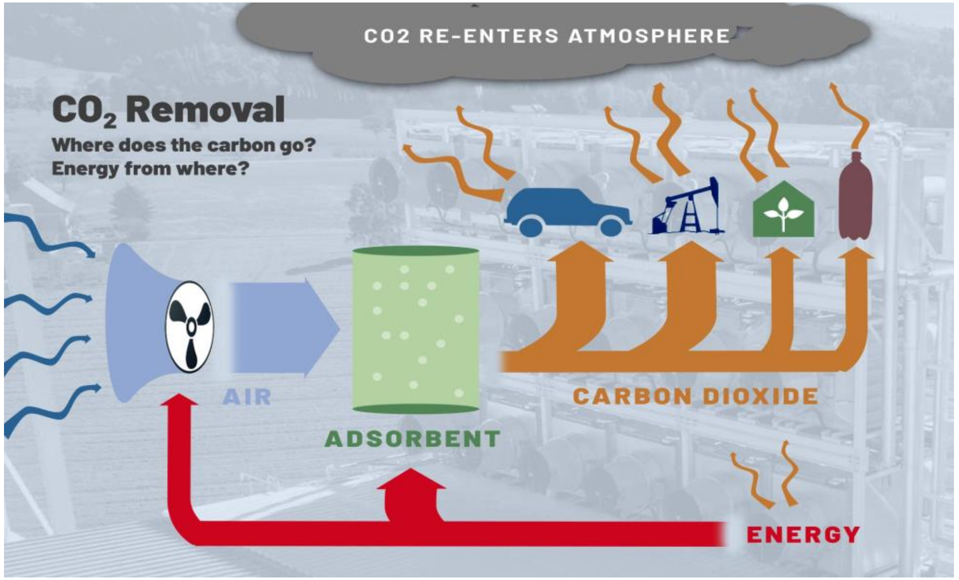
Tree carbon lifetime sequestration
40m height
60cm circumference



DIRECT AIR CAPTURE

>20,000 scale up needed

Direct Air Carbon Capture (DACC) developed by a few companies



Air driven by large fans is passed through a solution which removes CO2

DACC + Sequestration (DACCS) puts CO2 back into the ground

So far <10,000 tonnes CO2 removed permanently each year

Very expensive because atmospheric CO2 concentration is low (commercial proposition needed)

Global scaling - YES

MARINE PLANTING

Scale >20,000

Seagrass covers 0.2% sea floor but absorbs 10% of the oceans carbon
7% seagrass lost each year due to pollution & fertiliser run off

A square metre of seagrass generates about 570lbs oxygen each year
x2 the average tree

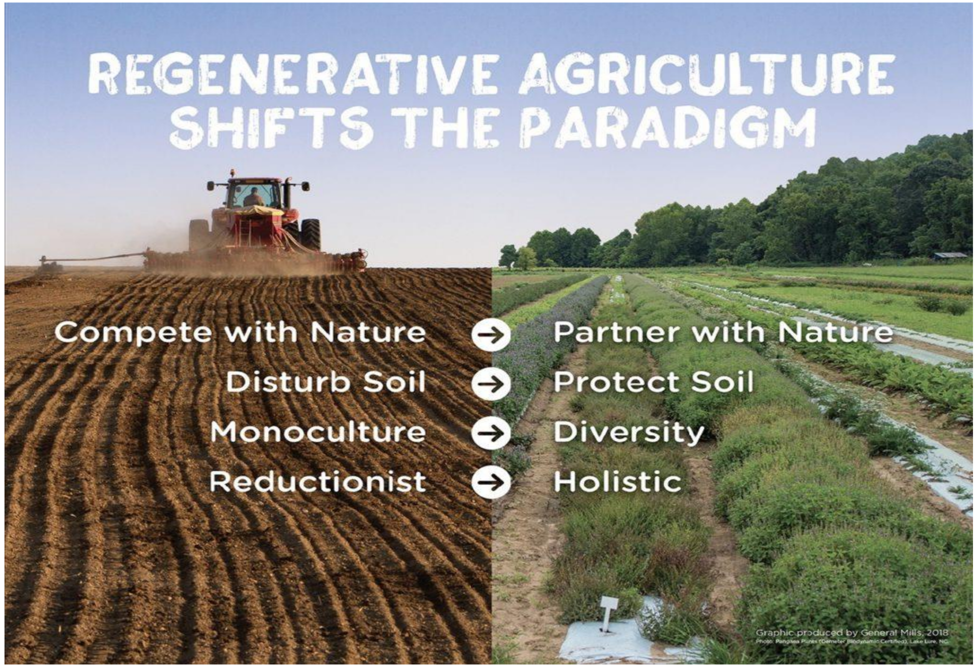
In 2014 x456 acres sea grass planted in Chesapeake Bay, Virginia
By 2015 it had grown to 6195 acres

Seagrass could be introduced into clean clear coastal waters

Scalable - YES

SOIL CARBON SEQUESTRATION

Scale >20,000



Change agricultural practices so the soil captures more carbon

Ground cover to absorb carbon dioxide into the soil through photosynthesis

Reduce use of fertilizers which generate green house gases

Minimize soil disturbance & improve the water cycle

Scalable - YES

LAND TRANSFORMATION SCHEMES

Regenerative Agriculture & Wildlife

African Valley

After Regeneration

Saudi Desert Area

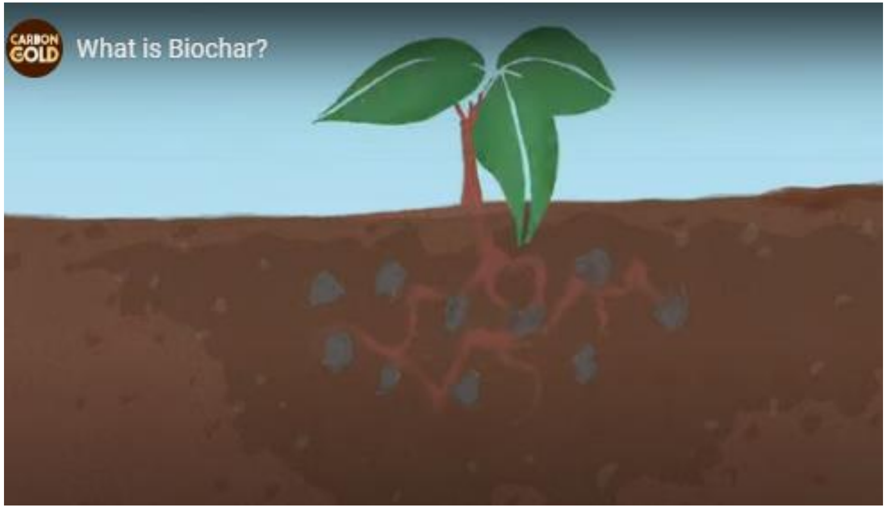
After Regeneration

1. Keep carbon & water in the ground to allow micro-organisms to flourish
2. Use a cover crop to maintain a healthy root system all year
3. Maximize crop diversity to fight pests & disease

BIOCHAR

Scale >20,000

Biochar is a very porous and high carbon form of charcoal for spreading onto fields



Biochar does not degrade and has 3 beneficial effects on soil:
Physical – the microscopic honeycomb structure improves the aeration, water holding capacity & nutrient retention

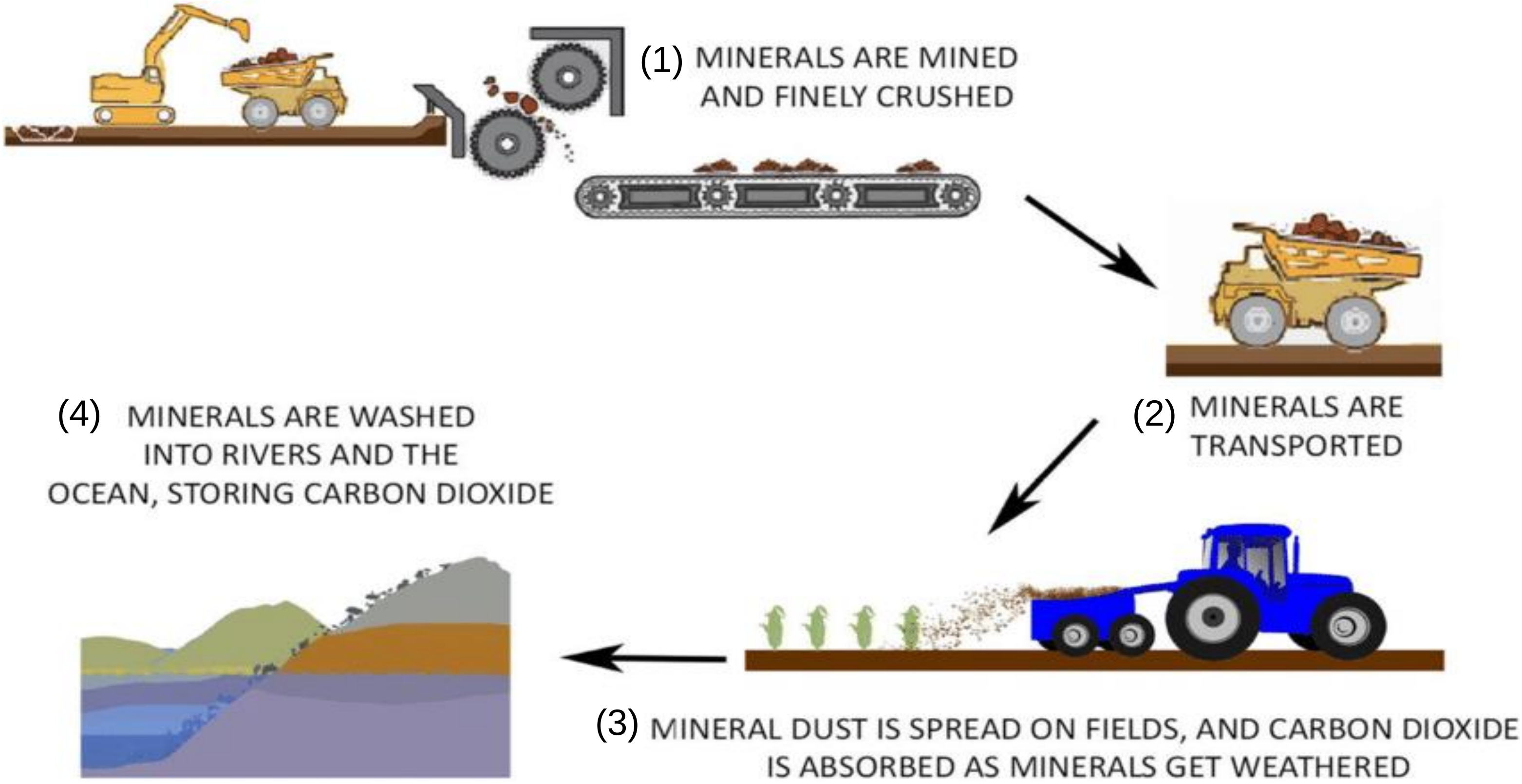
Biological – fights off pests by expanding soil microbial activity & diversity

Chemical – retains more carbon in the soil for plant use

Scalable - YES

ENHANCED ROCK WEATHERING

Accelerates carbon sequestration



Large crushed rock surface area + High CO_2 density in the soil + Water → Accelerated carbon sequestration

Scalable -YES

MICROBES WHICH EAT CO_2

Microbes are involved in the carbon and nitrogen cycles, and are responsible for both the production and consumption of greenhouse gases such as carbon dioxide and methane

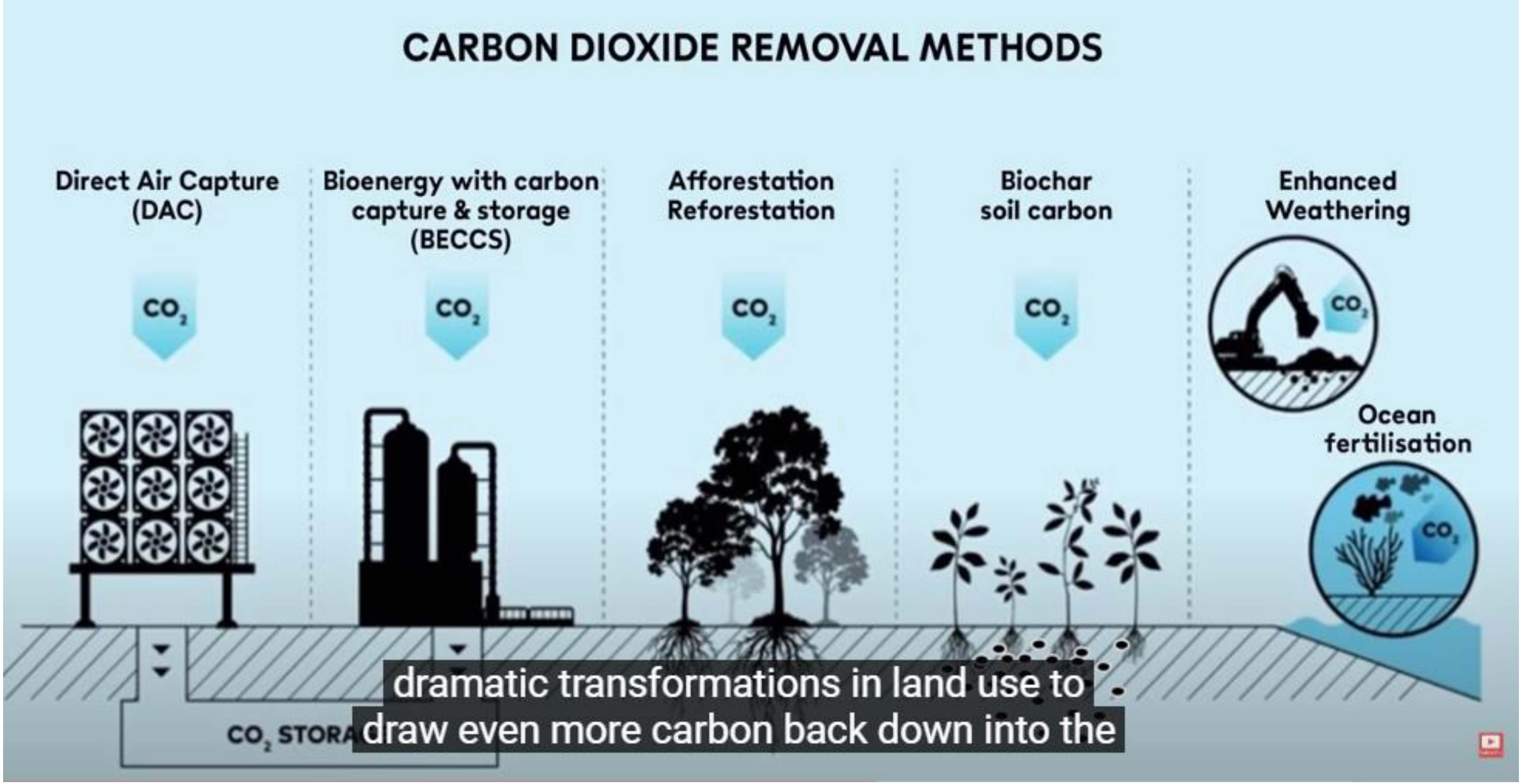
Discovery of carbon-capturing organism in hot springs could lead to efficient ways of absorbing atmospheric CO_2

Potentially enhanced by genetic engineering

Scalable - YES

DEPLOYMENT OF CARBON CAPTURE TECHNOLOGY

X20,000?



All Carbon Dioxide Removal Methods Can Be Scaled

SOLAR RADIATION MANAGMENT

Reflecting sunlight back into space

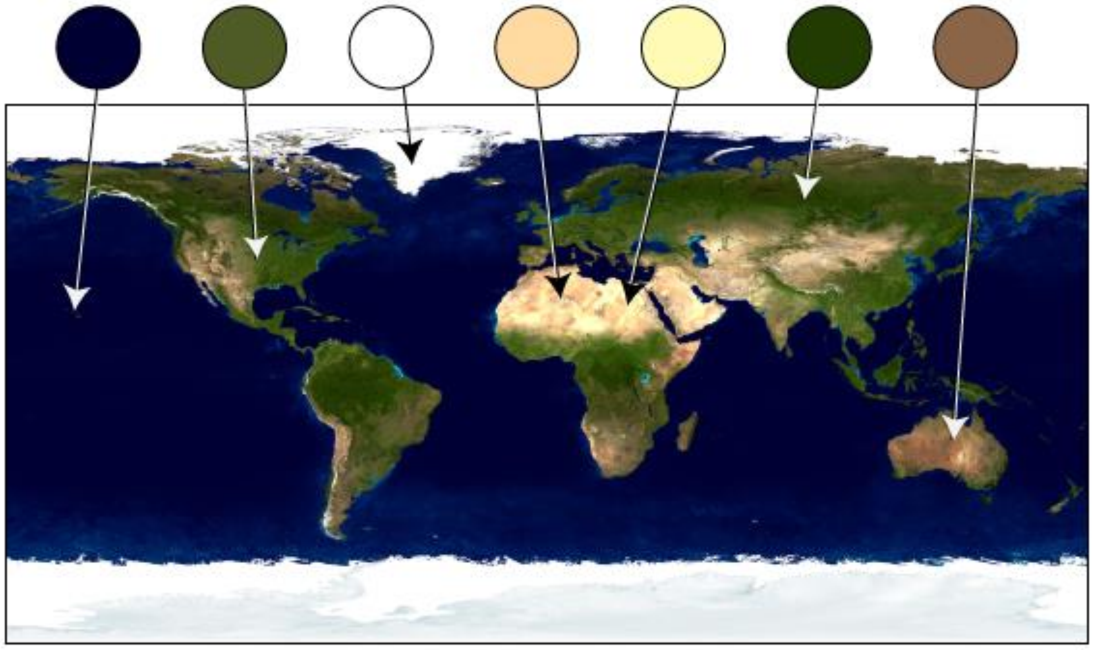
ALBEDO

Energy reflected by a surface is called albedo 0% -100%

The surface of the Earth is a patchwork of many colours (average albedo 31%)

Some are dark, such as the blue of the ocean, brown soil, and green forests

Other colours are pale, such as yellow desert sands and white ice



As Earth warms ice shrinks & deserts grow

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Forests have an albedo of about 15%

Fresh snow can have an albedo of 90%

How can we increase albedo of the planet by 5%?

MARINE CLOUD BRIGHTENING

Marine cloud brightening aims to increase the reflectivity of low level clouds to reflect more sunlight back into space

Works by accelerating cloud formation

Generate a fine mist of seawater by ocean going autonomous vessels powered by batteries

Uses only sea water and wind

Marine cloud brightening reflects up to 3.7W per square metre

Fast acting & reversible

Global or localised

Scalable - YES

OCEAN MIRROR

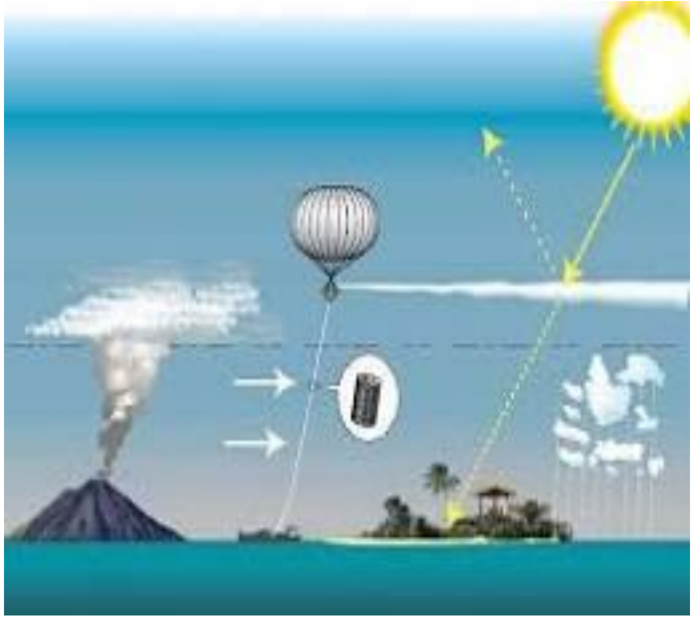
A fleet of autonomous solar powered sea vessels churn up millions of micro bubbles on the ocean surface

The reflectance of ocean foam can be x10 higher than the ocean itself
71% of our planet's surface is ocean

Scalable - YES

STRATOSPHERIC AEROSOL INJECTION

Introduce aerosols into the stratosphere to create a cooling effect from cloud generation
Occurs naturally from volcanic eruptions



Various forms of sulphur are proposed as the injected substance

Produces sulphur dioxide and hydrogen sulphide high up

Sulphate aerosols survive in the atmosphere for 3-5 days allowing the effect to spread over a wide geographical area

Could disrupting seasonal weather patterns leading to flooding or drought?

Needs to be much better understood

Scalable - YES

CIRRUS CLOUD THINNING

High altitude cirrus clouds prevent heat escaping into space

Cirrus clouds are composed of ice crystals & form at altitudes between 5 and 18 km at −38 °C

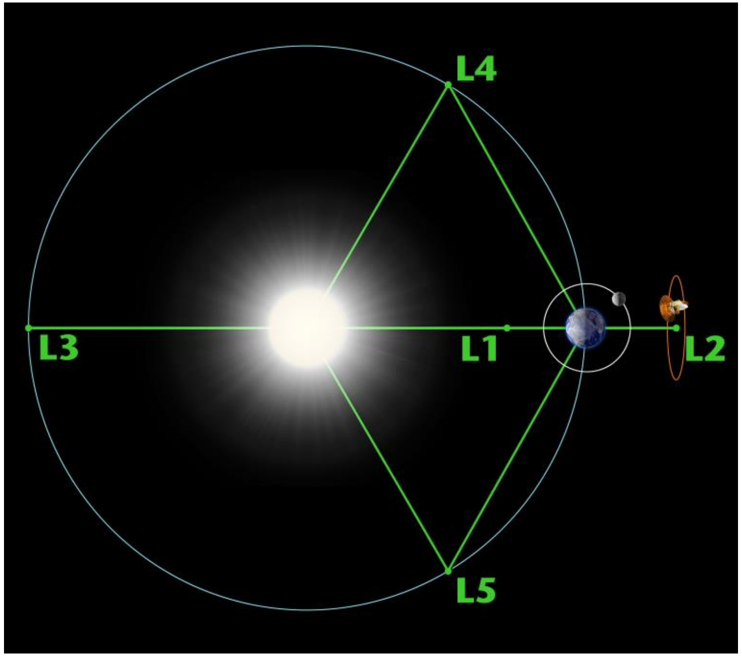
Injecting small particles makes the crystals larger & shorter lived dispersing the cirrus clouds

Allowing more heat to escape into space
Further work needed to demonstrate effectiveness

SPACE BASED REFLECTORS

Need to divert just 2-4% sunlight to take the Earth back to its pre-industrial climate

Installed at the L1 point 1 million miles from Earth

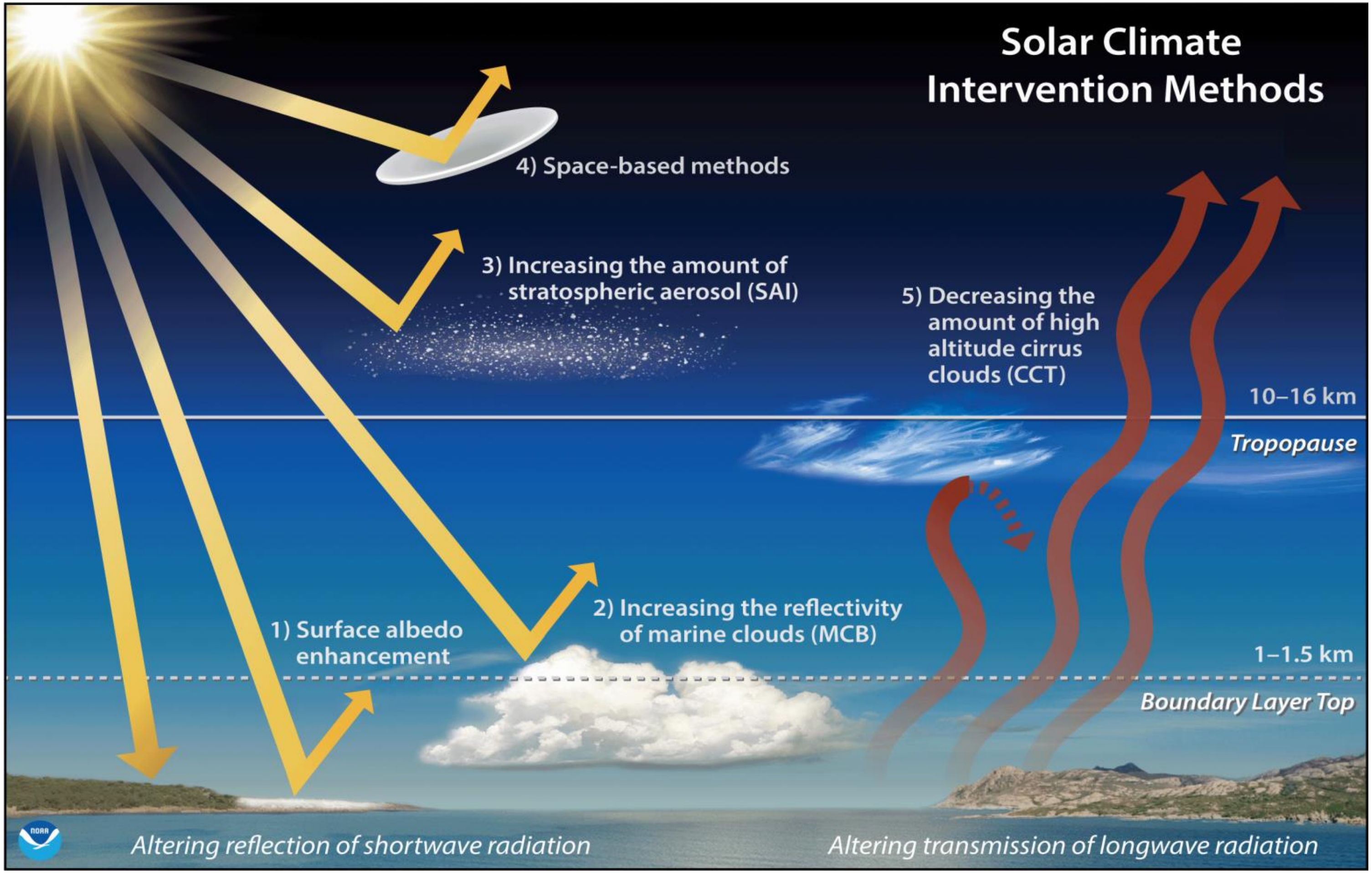


Disk radius of ~1000 km required (or modules with equal area)

Control the Earth's temperature

Challenge is getting the sunshade into outer space & maintaining its position

SOLAR RADIATION MANAGEMENT SYSTEM



Further work needed to quantify the effectiveness & understanding the risks

International agreement required on deployed solutions

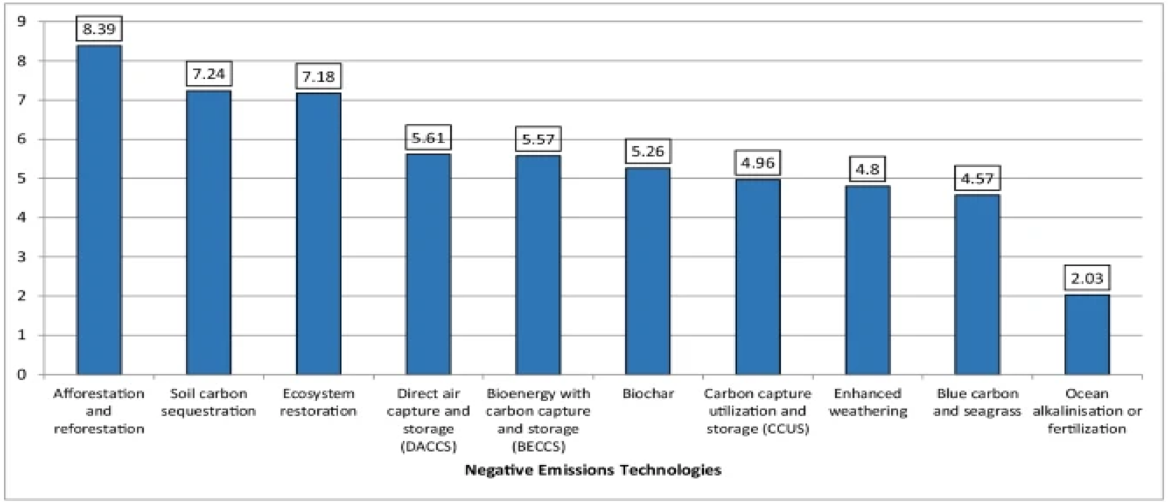
EXPERT ASSESSMENT OF GEO-ENGINEERING SOLUTIONS

Scale up by 10 – 100,000 needed

Solutions expert Rating x/10

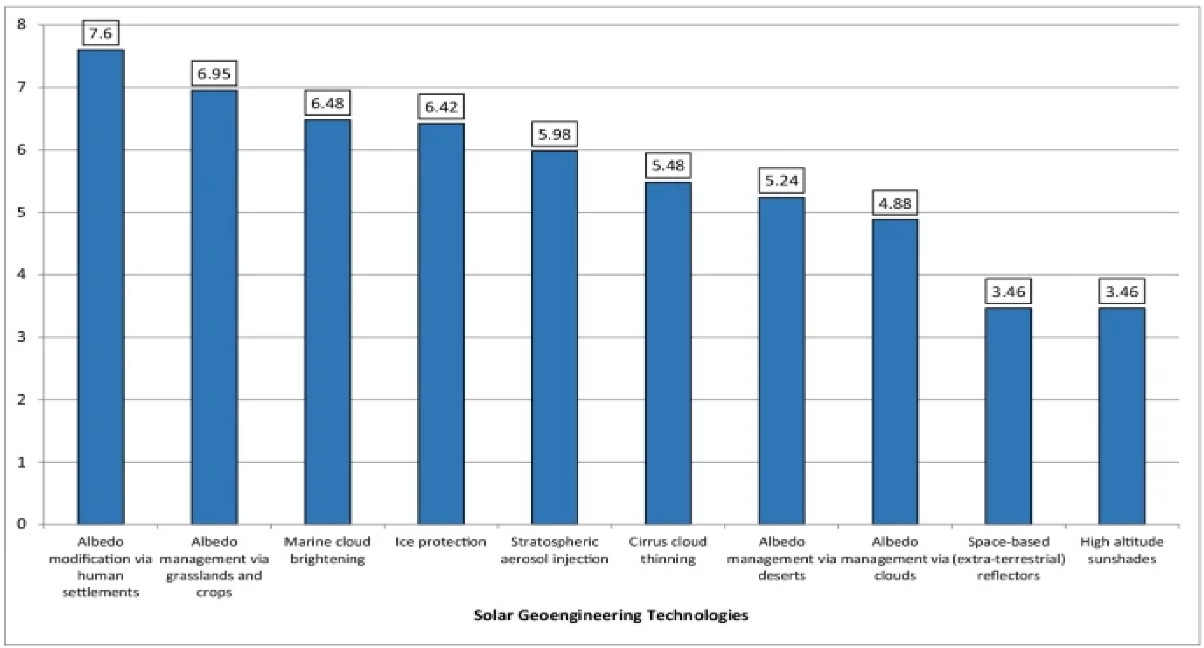
Carbon Capture

Trees, bogs & other methods



Solar Radiation Management

Reflecting sunlight back into space



GEOENGINEERING CHALLENGES

Geo-engineering is needed to maintain our current climate
Alternative to living in a +3C world

Solutions most likely a combination of CDR & SRM methods

Challenges are:
Scale solutions x100 – 100,000?
Understanding unintended consequences of geoengineering?
International agreement?

Who pays US, CHINA, EU, UN?

Should we create a geoengineering industry? YES

How can artificial intelligence help?
AI systems adapt autonomously without human intervention
Optimize & accelerate geoengineering solutions?
Come up with new approaches?