Is geoengineering the Naloxone to fossil fuel addiction?

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UBC squatters camp on čəsnaʔəm

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Talk overview

• A quick review of what is climate & how it is changed
• Impacts of climate change
• Available interventions
• Various types of geo-engineering
• Hubris, public perceptions & governance
• Discussion
The average temperature of earth is 31 degrees C higher than the moon.

95% of the earth’s natural greenhouse effect is from water molecules in the atmosphere.
An exceptional 10,000 yeas

Climate of the Past 800,000 Years

Climate of the Past 120,000 Years

~6° C difference between present day and last ice age.

Long period of stable temperatures lead to agriculture and societies
Deforestation, Agriculture, Irrigation, ...
Annual total CO$_2$ emissions, by world region

Source: Carbon Dioxide Information Analysis Center (CDIAC); Global Carbon Project (GCP)
Note: The difference between the global estimate and the sum of national totals is labeled “Statistical differences”. OurWorldInData.org/co2-and-other-greenhouse-gas-emissions • CC BY
Deforestation, Agriculture, Irrigation, ...

Atmospheric emissions of aerosols and greenhouse gases
Svante Arrhenius (1859 – 1927)

• A physicist and Nobel Laureate
• He was curious about the on-set and end of ice ages...
• He is the first to identify what is popularly called the greenhouse effect.
Impacts of climate change

• Less familiar weather
• More extreme weather events
• Sea level rise
• Positive feedback accelerating climate change:
  • Less sea ice and snow cover – making the earth’s surface darker and faster to warm
  • Melting of perma-frost and release of methane and CO$_2$ in arctic soils – adding to the greenhouse gases in the atmosphere at a rate that outpaces human emissions.
• ...

• 14
We have three options

- Reduce and eventually *reverse* our emissions of greenhouse gases.
- Adapt to a changing climate
- Deliberately change the climate system -- aka *geoengineering*
BC Energy Transition: History

- 2007 – GHG emissions 64.5Mt
- 2008 – Reduce emissions by 33% by 2020.

http://www.env.gov.bc.ca/soe/indicators/sustainability/ghg-emissions.html
As shown here, the sectors that shrank were manufacturing & electricity.

Carbon tax was on all building and transportation fuels.

Manufacturing declined due to insufficient investment, and trade
## Timing, cost & reversibility

<table>
<thead>
<tr>
<th>Contribution</th>
<th>Timescale for natural reversal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land cover</td>
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# Timing, intervention & reversibility

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<th>Contribution</th>
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<th>How</th>
</tr>
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<tbody>
<tr>
<td>Land cover ~ +18%</td>
<td>Half a century or more</td>
<td>Rethink agriculture &amp; forestry</td>
</tr>
<tr>
<td>Carbon dioxide ~+70%</td>
<td>600 years for 50% reduction</td>
<td>Transition out of fossil fuels</td>
</tr>
<tr>
<td>Methane ~+10%</td>
<td>10 years for 50% reduction</td>
<td>Transition out of fossil fuels &amp; livestock</td>
</tr>
<tr>
<td>Aerosols ±25% (but regional)</td>
<td>Days to weeks</td>
<td>Clean up fuel combustion</td>
</tr>
</tbody>
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Mitigation

• BC has made a lot of noise about their pioneering climate policies, but the policies have had very little effect.

• For $200/ton of CO$_2$ (or less) we can achieve a 100% transition out of fossil fuels:
  • Transport by 2040
  • Buildings by 2050
  • Industry (by same timeline if we have any left)
Mitigation + Geoengineering

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• And for less than 1% of the above, we can modify solar radiation!
Global Distribution of Blue Carbon Ecosystems

[Map showing global distribution of blue carbon ecosystems with categories for Mangroves, Salt Marsh, and Seagrass]
Figure 4. Locations of major artificial iron enrichment experiments, including the pilot demonstrations of GreenSea Venture and Planktos. Color heat map represents surface nitrate concentrations with warmer colors indicating higher concentrations, showing three major HNLC regions in the Southern Ocean, the eastern equatorial Pacific, and the subarctic Pacific. Data from National Virtual Ocean Data System, http://ferret.pmel.noaa.gov/NVODS/; analyzed nitrate data from the World Ocean Atlas 2005.
Artist’s rendition of a direct air capture CO$_2$ contactor tower
## Comparing options

<table>
<thead>
<tr>
<th>Nature of effort</th>
<th>Ease of deployment</th>
<th>Risks</th>
<th>Jurisdiction/Governance</th>
<th>Reversibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Afforestation</td>
<td>Plant and maintain for centuries</td>
<td>High effort &amp; medium cost</td>
<td>Fires; pest outbreaks; ecosystem</td>
<td>Contested</td>
</tr>
<tr>
<td>Coastal marshlands</td>
<td></td>
<td>Storms; diseases; ecosystem</td>
<td>Contested</td>
<td>Contested</td>
</tr>
<tr>
<td>Ocean fertilization</td>
<td></td>
<td>Medium effort &amp; low cost</td>
<td>ecosystem</td>
<td>Poor</td>
</tr>
<tr>
<td>Direct air capture</td>
<td>Continuous action</td>
<td>Highest effort &amp; cost</td>
<td>Leaky storage</td>
<td>No issues</td>
</tr>
<tr>
<td>Solar radiation management</td>
<td>Least effort &amp; cost</td>
<td>Altered climate</td>
<td>Poor</td>
<td>Rapid</td>
</tr>
</tbody>
</table>
David Keith & I had four reasons for suggesting a deep study of geoengineering in 1992

1. The scientific understanding of anthropogenic climate change was already established.
2. The world had twice visited the Fossil Fuel Addition Clinic (1973 & 78) and was more dependent on fossil fuels than ever.
3. Extreme climate effects may compel some politicians “to act” unilaterally.
4. The only cheap and fast acting response is solar radiation management – so “the actor(s)” would probably use it.
Deforestation, Agriculture, Irrigation, ...

Make Whiter, more persistent clouds
Deforestation, Agriculture, Irrigation, ...

Make aerosols to make the sky brighter

Make Whiter, more persistent clouds
2 ways aerosols interact with clouds

Cloud whitening

Normal Cloud has fewer large droplets of water

More aerosol particles lead to far more (and smaller) water droplets.

This makes the cloud whiter and reflects out more incoming sunlight

Cloud longevity

Rain is more likely in clouds with larger water droplets

Smaller water droplets mean clouds last longer.

Adapted from: Robert Wood, U of Washington
Deforestation, Agriculture, Irrigation, ...

Put Sunshades in space

Make Whiter, more persistent clouds

Make aerosols to make the sky brighter
Mt Pinatubo 1991

One of the most spectacular volcanic eruptions in recent memory. Injected a large plume of sulfate rich aerosols into the stratosphere.

The white aerosol particles reflected sunlight falling on top of the atmosphere and the earth cooled!
Mt Pinatubo 1991
Mt Pinatubo 1991

The eruption

No change in Temp
Concerns about using stratospheric aerosols for solar radiation management

- Harm to the ozone layer in the stratosphere
- Harm to ecosystems on earth
- Inadvertent changes to climate
- Not a full substitute for mitigation &/or Carbon Capture & Removal
- Governance
- Long-term dependence
Smoke Rising into the stratosphere after the 2019/2020 Australian Bushfires

Preprint/ Khaykin et al., 2020

https://www.researchgate.net/publication/342168784_Australian_wildfires_cause_major_perturbation_of_the_stratosphere_and_generate_a_self-maintained_smoke-charged_vortex_rising_up_to_35_km

Adapted from: Jean-Paul Vernier, NASA
Harm to the Ozone layer

• We thought only man-made chemicals (like CFCs) & large volcanoes could reach the stratosphere.
  • Over the past three years we have had large forest fires so hot that their smoke plumes has risen into the stratosphere.
  • We need to consider the risk of deliberate use of chemically neutral aerosols against highly reactive smoke plumes from avoided forest fires.
Harm to ecosystems & agriculture

• Modeling suggests that the ideal is to use geoengineering to counteract only half the effects of GHGs.
  • The average level of sunshine on earth is 340 Watts per metre squared.
  • Higher greenhouse gas concentrations have increased radiative forcing by roughly 3.5 Watts per metre squared (or ~1%)
  • So, ideally, SRM would reduce incoming radiation by 0.5%.

• We know that less sunshine means less photosynthesis. This 0.5% reduction in sunlight reaching the earth is like having a slightly cloudier year. The year to year variation in cloud cover around the world is far greater than 1%.
Stratospheric aerosols would use:
• 500,000 Tonnes/y of specially manufactured inert particles;
• costing about $30 B/yr to make and put into the stratosphere.
Inadvertent impact on climate

We do not know how we were blessed with a 10,000 year period of exceptional climate stability. We do not know what could make us lose this climate stability. What we do know is that we have not had any significant GHG mitigation to date.

- Forestry, agriculture, industry, urbanization, … all lead to long-term unintended modifications of the climate system.
- Geoengineering is an intentional attempt to put right what we have been doing wrong.
- Could we screw it up any worse by reducing radiative forcing?
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• Geo-engineering is an intentional attempt to put right what we have been doing wrong for centuries.
• Could we screw it up any worse by reducing radiative forcing?
Not a substitute for all GHG impacts

- SRM can be used to reduce global temperature change but the pattern of climate change will be different
- SRM cannot reduce CO$_2$ in the atmosphere, so the oceans will continue to acidify
Governance & public perceptions

• The technology for aerosol SRM is simple, cheap and available. No “power” can stop an individual, corporation or country from deploying it.

  *For example: I would not be surprised if PM Modi does not launch SRM to restore the Indian monsoon.*

• Public perceptions are highly prone to manipulation because reasoned and well-informed decision-making is in short supply.
My worry: Our experience with Naloxone!

• I was delighted to find out that there is a drug that is cheap, fast acting and can help overdose patients recover consciousness.

• I am horrified that many saved by Naloxone, become regular users.
SRM can buy us time but we must transition to renewable energy

• Many, especially older members of the population, are under the impression that giving up fossil fuels is a huge shift in lifestyle, costly and even painful.

• I do not understand:
  • Europeans live prosperously with similar incomes and energy prices 3-5x higher than us.
  • Most EU countries have economies built on value added activities. Why do we want an economy based on extraction of natural resources in the hands of foreigners?
  • Building more efficient housing and renewable energy is not a “cost” but an investment that employs local labour and stimulates related industries/exports.
Summary

• This civilization emerged from an exceptional period of climate stability.

• Our changes to land and atmosphere have increased energy retained in the earth’s atmosphere and oceans by 1% and growing.

• We have made negligible progress in slowing climate change.

• We have the probability of run-away climate change and will need an emergency response.

• ... aerosol Solar Radiation Management is a stop-gap while we get out of oil & gas (cheap, fast acting, and reversible).
Questions?
Indiana's Forest Cover

1820

100

0

Percent Forest

1700

Today

2001

Forest

Wetland

Dry Prairie

Developed

Agricultural

Northern Moraine

Central Till Plains

Southern Hills
earth's energy budget

incoming solar radiation 340.4
reflected by clouds & atmosphere 77.0
reflected by surface 22.9
total outgoing infrared radiation 239.9

absorbed by atmosphere 77.1
total reflected solar radiation 99.9
absorbed by surface 163.3
emitted by atmosphere 169.9

emitted by clouds 29.9
atmospheric window 40.1
greenhouse gases

back radiation 340.3
latent heat (change of state)
thermals (conduction/convection)
evapotranspiration

net absorbed 0.6

All values are fluxes in Wm⁻² and are average values based on ten years of data