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Science, Technology and Society

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Geoengineering Game Experiment for STS4500: A fourth year course for engineering students

Begin Here: Engaging with Climate Engineering (CE) in an STS course targeted at Engineering Students

1. Basic Premise: This is a role-playing game that introduces the idea of climate engineering as a global conversation, not just a conversation among expert communities. The basic procedures are incredibly simple and can be conducted quickly (sub-30 minutes) or over a span of days to allow for deeper conversation and negotiation. The intent is to have a robust conversation on the reasons why decisions were made and the end result of the "global" engagement with climate change mitigation.
2. The game can be altered in several ways to match with different education goals
    a. Understanding Technoscience and Controversy: Students will have to research each type of climate engineering option and come up with the costs, pros, and cons. This encourages a deeper understanding of the issues as well as investment in the outcome of the game as it unfolds in the classroom. The instructor can have executive power to modify any aberrant submitted options.
    b. Understanding Context and Governance of Technoscience: Country representation can be set by the instructor, be chosen by the students from real world examples, or have them make up a country so that they might experience a different sort of engagement with cultural and sociopolitical context for technoscientific interventions. Giving time to build awareness of the stakeholders is critical so that they do not default to what they are most comfortable with. For example, in one semester three different sections had three different portrayals of what the U.S. would do. One was completely defeatist and stated the U.S. would do nothing proactive. A second reflected on local and state attempts to work on climate change issues and stated that they felt like Americans could get behind some of the options, particularly when they might be related to national security issues. A third took it upon themselves to argue that CE wasn't viable nor was the core of the issue, rather an option outside of the game was essential with education and demand reduction.
    c. Ethical Responsibility and Inequality: Countries representatives can coordinate with other plays to conduct climate change engineering projects. This more closely resembles some of the strategic options for encouraging protecting rainforests or positioning the CE interventions in less inhabited regions or where it might cost (monetarily) less to implement.
    d. Expertise: The different stages of the game can be conducted with full transparency during the class, or each group will offer up their choices only to the instructor (or student leader). Tallies would be made at the end of the session. This offers up the opportunity to explore how experts don't operate with full knowledge of how their decisions might be in conflict with or synergistically aligned with other stakeholders. For example, in one game several groups felt a moral obligation to use a large percentage of their GDP to combat climate change using Climate Engineering. I had not anticipated this outcome at this level and the end result was a mini-ice age as we layered several interventions on top of one another.
    e. Risk and Agnotology: The inclusion of the dice roll can be used as a means of introducing a factor or "known unknowns" into the game. Each CE option contains positive, negative, and ambiguous outcomes depending on the roll of a 6-sided dice. More options can be introduced simply be using a larger n-die. The example game includes scenarios where the risks are local or are shifted to other regions so as to simulate the potential that other stakeholders will be impacted even as oneself remains safe. Neutral and positive options are included so as to introduce an element where the players might be lulled into overconfidence due to perceptions of low risk (two bad options out of six) or institutionalized risk perception (several groups roll positive/neutral).

Basic Introduction of a Quick Example Game and Discussion Created by the Instructor with no Student Input

The game mechanics of this game are fairly simple. The goal is to generate discussion of the ethics, responsibilities, and contextual challenges of attempts to "fix" climate change problems. Each group represents a country and you should position your thoughts and actions with a goal to understand how different members of that society might consider geoengineering at a local and global level. Each group will investigate the options I have presented, the socioeconomic options and hurdles, and determine what interventions you might take. There is no pre-determined means of winning and the options presented are not all inclusive. The few restrictions one has on choices is the GDP for each member state. One can't simply "solve" the problem by spending $trillions when one does not have $trillions available.

Stage 1: Group formation and Exploration of Interventions [instructor option for group allocation]

Quickly get into representative country groups (3-6). Take 10 minutes to explore the intervention options. I will clarify any questions during and after this period of time.

Stage 2: Three Rounds of Selection and Discussion [presentation conducted with full transparency to class]

Round 1:

Take 15 minutes to discussion with your group what options you are going to take for Round 1

Presentation of Contribution

1. Plan on discussing your justifications for selection (moral, economic, technical, etc.);
2. Note what you expect other countries to take responsibility for;
3. Suggest alternative options not provided;
4. Each group rolls for possible side effects;
5. Note choice and side effect on contribution calculator sheet.

Round 2:

Take 10 minutes to discussion with your group what options you are going to take for Round 2

Presentation of Contribution

1. Plan on discussing your justifications for selection (moral, economic, technical, etc.);
2. Note what you expect other countries to take responsibility for;
3. Suggest alternative options not provided;
4. Each group rolls for possible side effects;
5. Note choice and side effect on contribution calculator sheet.

Stage 3: Final tally of results and group discussion

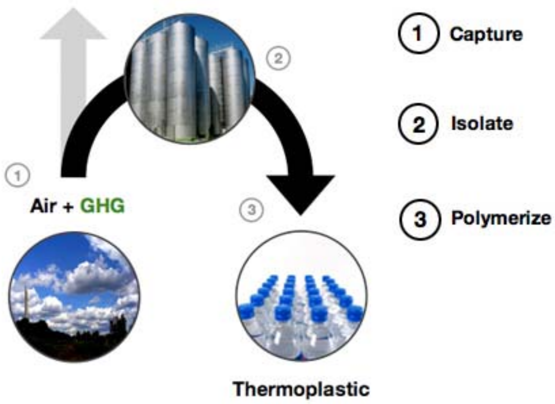
Stage 4: Writing Reflection due on what your thoughts are on Climate Engineering and the processes/outcomes of the game due before next class.

Direct Capture C02 from Towers in Cities

0% of localized GHGs and 10% of Pollutants Collected if not using fossil fuel energy use ($27/ton CO2)

30% of localized GHGs and 30% of Pollutants Collected if using renewable fuel sources ($150/ton CO2)

Requires dramatic increase in R&D to optimize turning gases into permanently stable materials



Potential Impacts Could Also Include:

1. Increased energy costs for areas with towers
2. Increased use of Coal and other Fossil Fuel resources due to perception shift that emissions are mitigated
3. Potential CO2 escaping if not continuously monitored or stored in durables
4. Secondary Benefits include co-locating with Greenhouses for crop production and decreased health harms from local smog and airborne particulates
5. R&D can be exported to non-participating countries (if no other groups roll 5 of 6 then reduce total costs/ton by 25%)
6. All of the above

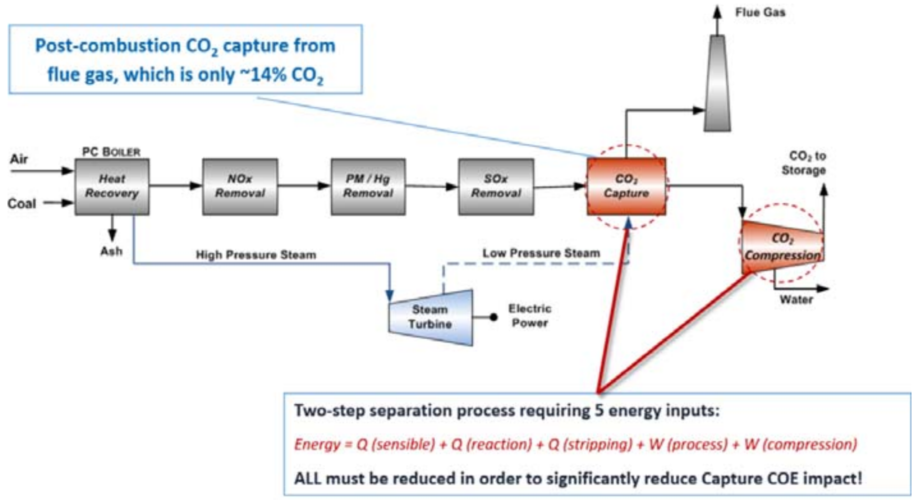
Capture C02 from power plants with geological storage

Requires permanent stewardship so CO2 doesn't leek out in the future

Deployed widely, 23% of global CO2 emissions could be captured

Secondary Benefits include scrubbing additional pollution sources from air

Cost: $50/ton CO2



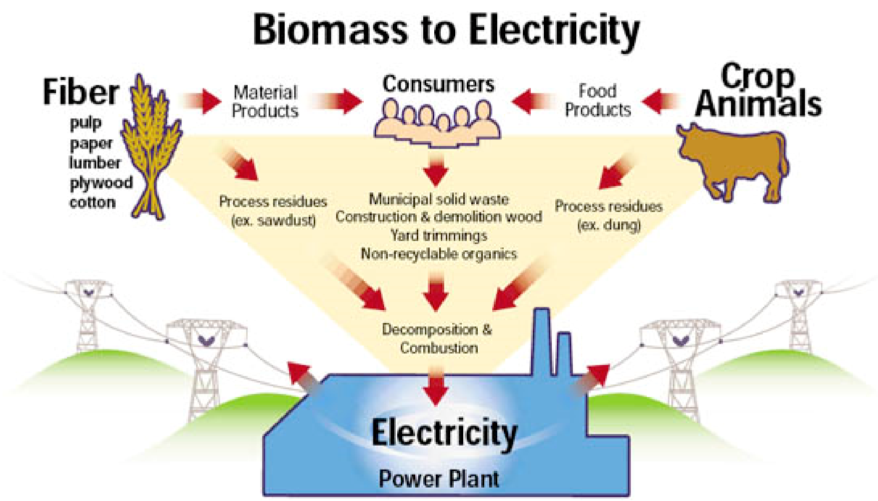
Potential Impacts May Also Include:

1. Increased energy costs
2. Increased use of Coal and other Fossil Fuel resources due to cleaner burning
3. Potential CO2 escaping
4. Groundwater contamination
5. CO2 benefit offset by large scale transportation and storage needs of resulting carbonates
6. None, everything works out somehow

Shift to Bioenergy for Energy Generation

10% Global CO_2 offset possible

Cost: \$25/ton CO_2



Potential Impacts May Also Include:

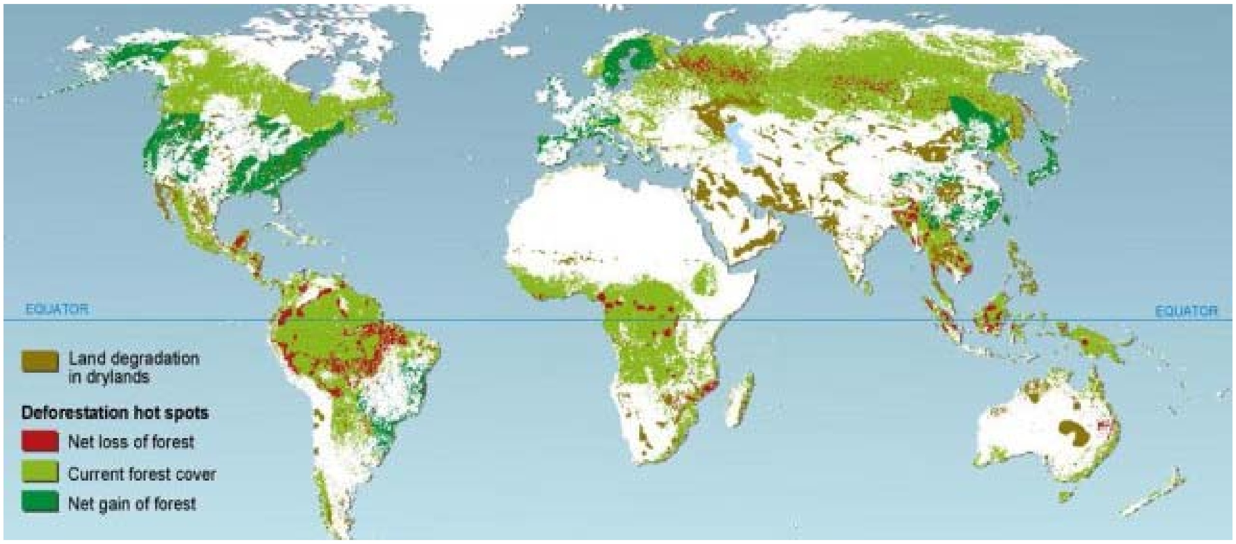
1. Land use changes cause food shortages in other countries
2. Land use changes cause food costs to increase locally
3. Runoff of fertilizers and pesticides increase
4. Farming is further centralized and more small farms shut down
5. None, everything works out somehow
6. Deforestation increases due to demand for agricultural land

Reforestation

Potential 5% Global CO_2 offset

One billion metric tons of CO_2 offset requires between 100-500 million acres.

Cost: $10/ton CO_2 if in U.S., EU, Korea, or Japan (money goes to another country); $5 otherwise



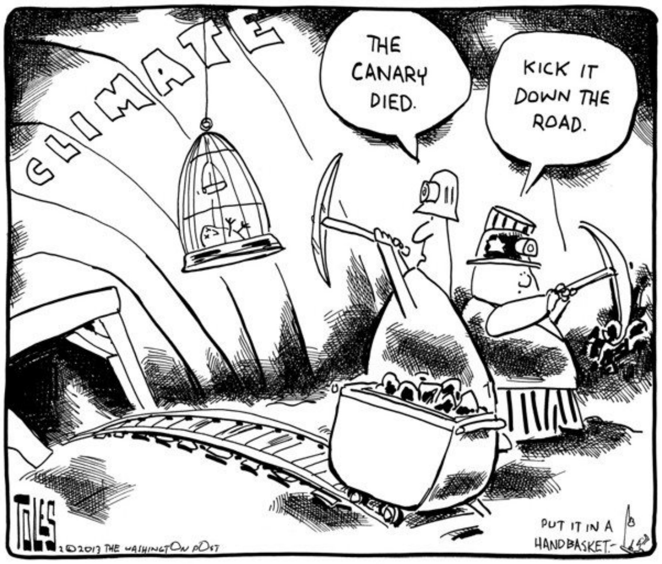
Potential Impacts May Also Include:

1. Land use changes cause food shortages and local communities are displaced
2. Demand for bioenergy exceeds demand for reforestation; initial investments fail
3. Secondary soil erosion control improves and species diversity increases
4. {Unless you are in a tropic region} The impact of reforestation is negligible or even causes methane release and heat trapping
5. Initial success in reforestation requires heavy application of fertilizers, waterways are further polluted
6. All of the above

Keep with the Status Quo

Direct costs are effectively zero

Supporting continued scientific evaluation of issue and wait for further evidence



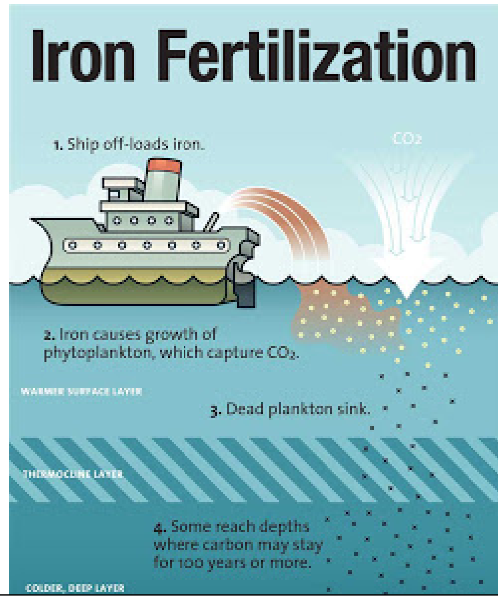
Potential Impacts May Also Include:

1. The money you save on not spending on climate change adaptations is used to bolster some sectors of the economy
2. You lose billions in trade opportunities in some sectors due to explosive growth of new industries in other countries
3. You are negatively impacted by geoengineering projection conducted in other regions, flooding and droughts become more common
4. You lock in for another century of using GHG emitting technologies
5. Some regions in your country experience massive heat waves, floods, fires, and cold shocks but catastrophes end up happening elsewhere.
6. All of the above.

Ocean Fertilization Seeding

Potential 4% of global CO_2 emissions offset

Cost: $8/ton CO_2



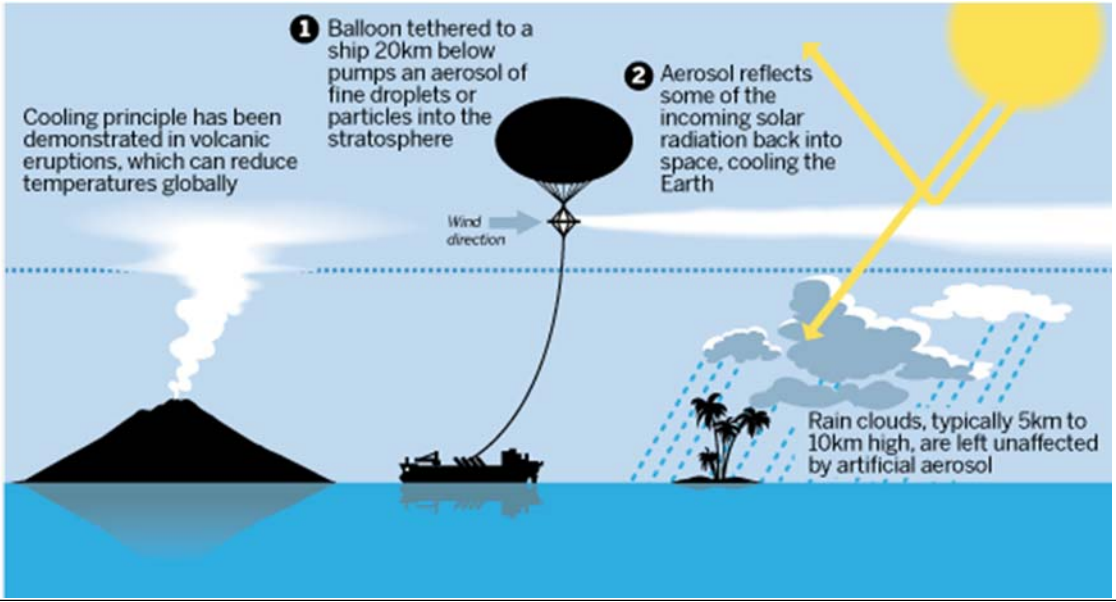
Potential Impacts May Also Include:

1. Fish stocks also benefit from new food sources
2. Red tides and other toxic blooms also occur, people and marine life get sick
3. De-oxygenation occurs in deeper waters as ecosystem is driven into overdrive
4. Phytoplankton itself produces local toxic level of domoic acid, local marine life struggle for months after seeding
5. Amount of phytoplankton needed to actually have an impact greater than expected, lower offset to 1%
6. No local or global problems arise

Inject Aerosols into Stratosphere

Potential 100% warming effect negated

$2/ton



Potential Impacts Also Include:

1. Changes in precipitation cause flooding in some regions, droughts in others, and shifting Monsoon schedules for most of Africa and Asia
2. Increased acid rain deposition which can negatively impact marine and terrestrial ecosystems
3. Success breeds public complacency on GHG emissions, temperature stability causes dismissal of other harms. GHG emission actually increase with associated harms
4. Solar panels have reduced efficiency and plant life has less solar radiation for growth
5. Regional variability of climate causes localized disruptions of farming, fishing, and other industries
6. All of the Above

Contribution calculator: Round 1			
Type of Intervention	Cost Per Ton	Dollars Contributed per Year	Tons CO2 Offset (include modifiers)
Direct Capture C02 from Towers in Cities	27/150		
Capture C02 from power plants with geological storage	50		
Shift to Bioenergy for Energy Generation	25		
Reforestation	5		
Ocean Fertilization Seeding	8		
Keep with the Status Quo	0		
Inject Aerosols into Stratosphere	2		

Side Effects:

Contribution calculator: Round 2			
Type of Intervention	Cost Per Ton	Dollars Contributed per Year	Tons CO2 Offset (include modifiers)
Direct Capture C02 from Towers in Cities	27/150		
Capture C02 from power plants with geological storage	50		
Shift to Bioenergy for Energy Generation	25		
Reforestation	5		
Ocean Fertilization Seeding	8		
Keep with the Status Quo	0		
Inject Aerosols into Stratosphere	2		

Side Effects:

Additional Economic and Emissions Information

Country/Economy	GDP Nominal (billions of $)	
	2016	Share
United States	18,561	24.7%
EU	16,311	16.9%
China	11,391	15.1%
Japan	4,730	6.29%
India	2,250	2.99%
Brazil	1,769	2.35%
Canada	1,532	2.04%
Korea	1,404	1.87%
Russia	1,267	1.69%
http://data.worldbank.org/		

Country	CO_2 emissions (kt) in 2014	% CO_2 emissions by country	Emission per capita (metric tons) in 2014
World	35,669,000	100%	5.0
China	10,540,000	29.55%	7.6
United States	5,334,000	14.95%	16.5
European Union	3,415,000	9.57%	6.7
India	2,341,000	6.56%	1.8
Russia	1,766,000	4.95%	12.4
Japan	1,278,000	3.58%	10.1
South Korea	610,000	1.71%	12.3
Canada	565,000	1.58%	15.9
Brazil	501,000	1.40%	2.5

Game Details and Discussion Citations

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