Clean Coal: Resolution or Ruse?

Fargo Nerd Night: November 14, 2018

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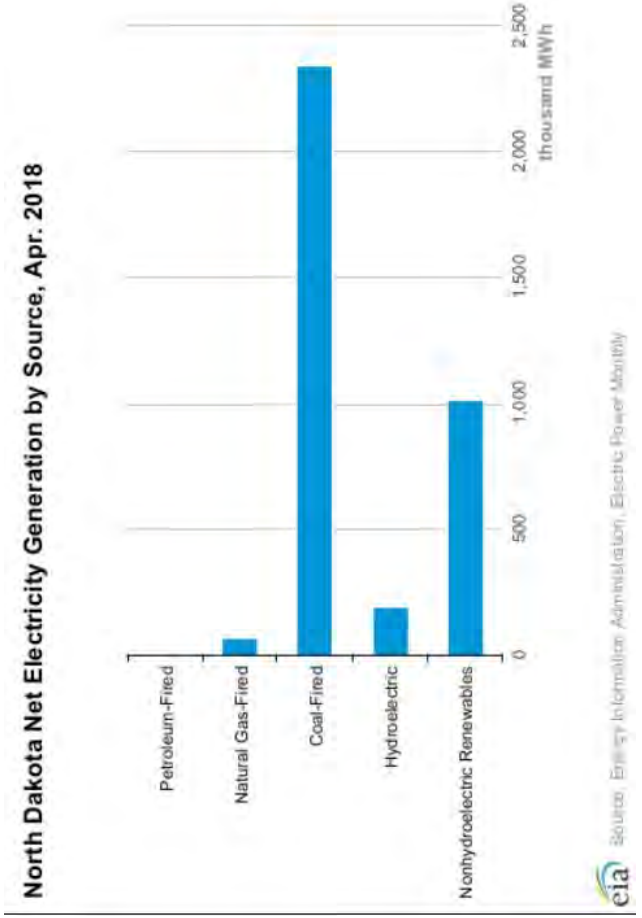
The first principle is that you must not fool yourself -- and you are the easiest person to fool.

Richard Feynman

Background

- ND produces 65% of its energy from coal
- Coal produces large amounts of CO_2
- CO_2 is a pollutant (EPA) detrimental to human health and planetary health



Carbon Sequestration

a.k.a. Clean Coal

- $C + O_2 = CO_2 + heat$
- Carbon Sequestration seeks to eliminate or bottle up the CO_2
- Other pollutants (Hg, S, etc.) are not addressed
- Four proposed methods are
  - Oxy-Fuel Combustion
  - Capture CO_2 in Limestone Deposits
  - Capture CO_2 in Olivine
  - Underground Storage

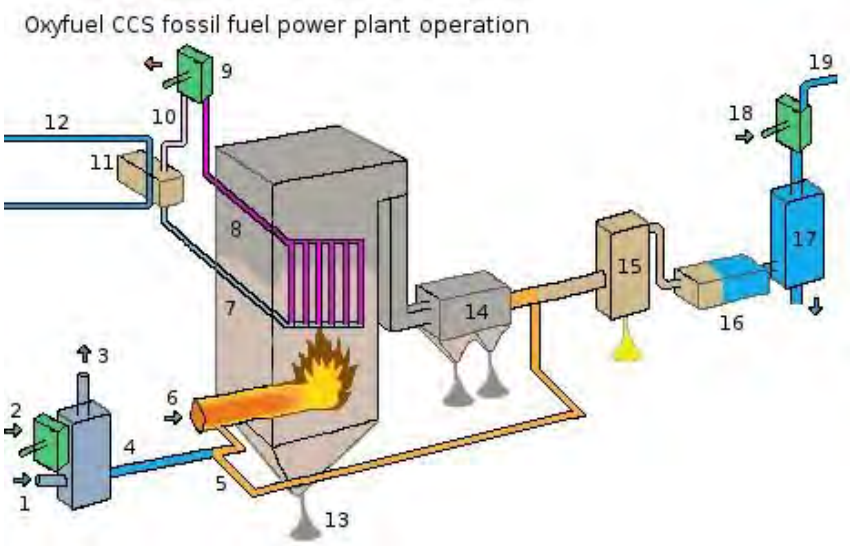
Our contention

- Clean coal does not exist
- Clean coal proposals do not and cannot work
- Some of us in C.L.E.A.N. believe that clean coal is little more than a ruse to confuse the public and politicians in an effort to extend the life of coal - similar to tactics used by the tobacco industry

Oxy-Fuel Combustion

a.k.a. Allum Cycle: Carbon Sequestration Method #1

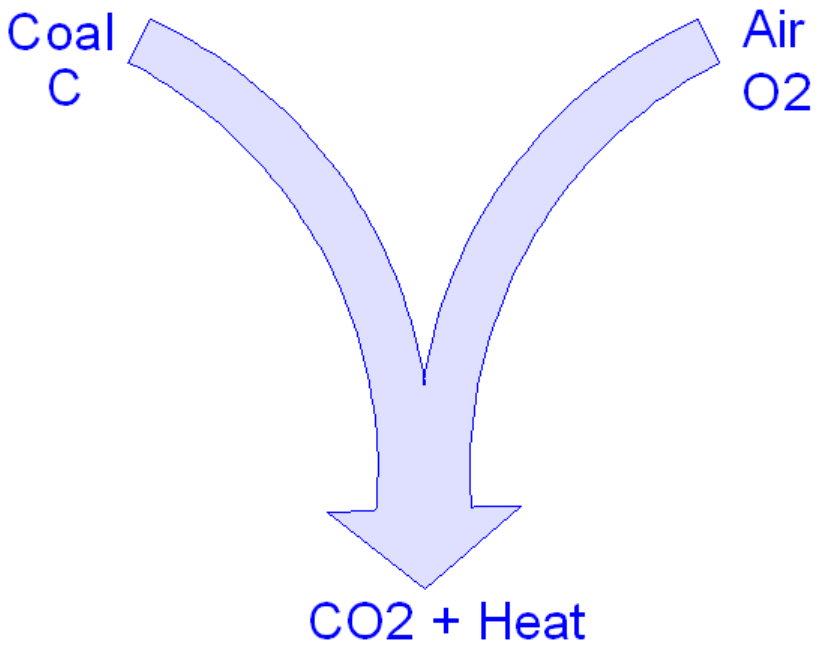
- Air consists of 70% Nitrogen
- The hotter a furnace becomes, the more efficient it is (good)
- The hotter the furnace becomes, the more nitrous oxides are formed (bad)
- Oxy-Fuel Combustion burns coal with pure oxygen atmosphere, allowing
  - Higher temperatures
  - Without producing nitrous oxides
  - Without the need of smokestacks



Oxy-Fuel Combustion

Problems

- It takes energy to make pure oxygen
- You still produce the same amount of CO_2 as a byproduct



Capture CO_2 in Limestone Deposits

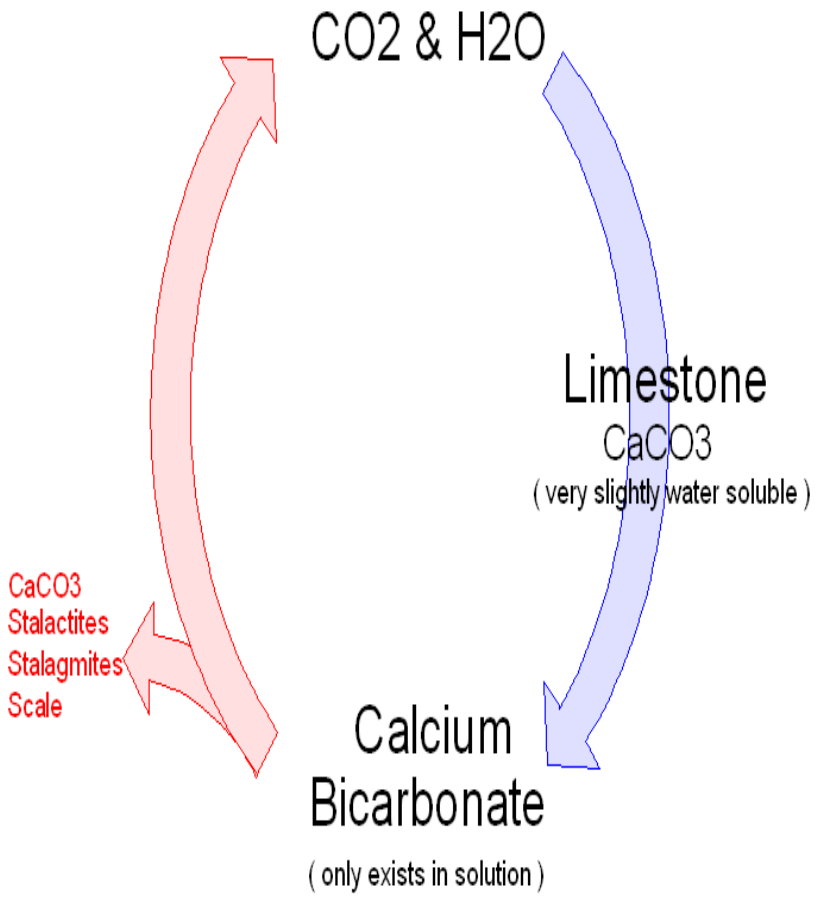
Carbon Sequestration Method #2: Idea

- If you pump CO_2 into limestone caves, a chemical reaction takes place capturing the CO_2.
- This is how limestone caves are made

Capture CO_2 in Limestone Deposits

Chemistry

- Pass CO_2 and water through a limestone deposit and you get calcium bicarbonate.
  - The limestone is dissolved (creating a cave or empty space)
  - **The CO_2 is captured and placed in solution**



Capture CO_2 in Limestone Deposits

Problem #1/3

- The U.S. burns 728 million tons of coal each year
- This produces 5,924 million tons of CO_2
- Which requires 2760 million cubic yards of limestone to capture the CO2 each year
- We need to create a limestone cave, 200x larger than the largest limestone cavern each year

Capture CO_2 in Limestone Deposits

Problem #2/3

- Calcium Bicarbonate does not exist in solid form. It must remain in solution
  - You cannot recycle or reuse the water
- Calcium Bicarbonate decomposes into limestone and CO_2
  - This is how stalactites form
  - This is how scale is formed in pipes
- The net result
  - CO_2 is captured for only a short time
  - All you've done is move the limestone from one place to another

Capture CO_2 in Limestone Deposits

Problem #3/3

- It takes thousands of years to make a limestone cave
  - For illustration, stalactites form at a rate of 1-2 inches per century
- We're trying to speed up the process to 2760 million cubic yards each year
- The process doesn't speed up: limestone just isn't that soluble in water.

Capture CO_2 in Olivine

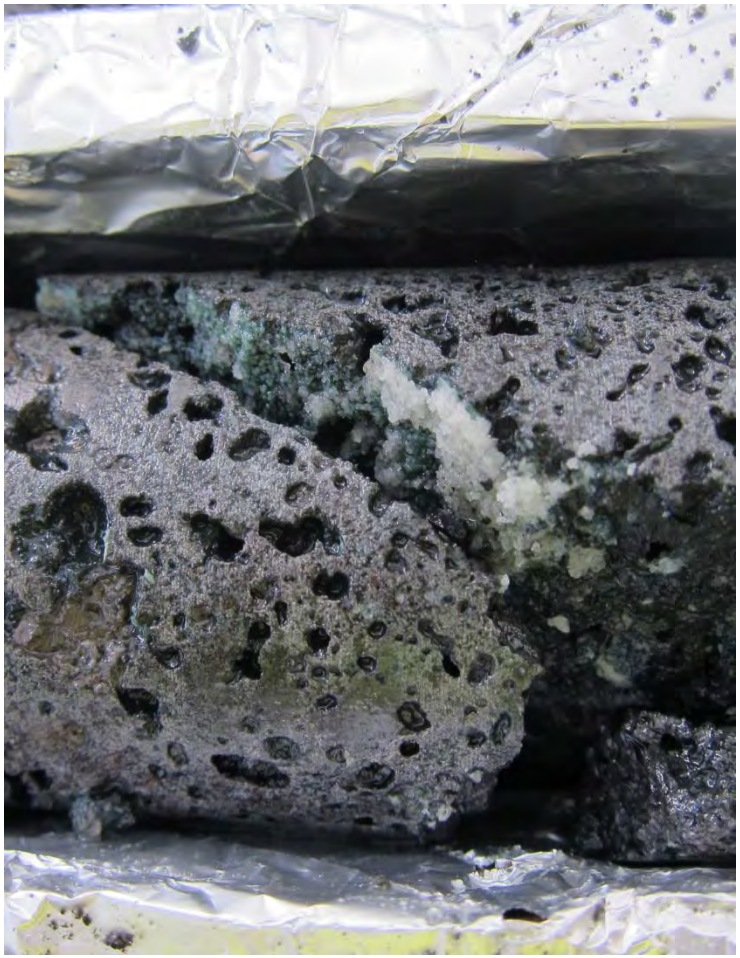
Carbon Capture Method #3

- Columbia Univ and Climeworks report they *have* turned CO_2 into rock
- https://www.ldeo.columbia.edu/gpg/projects/carbon-sequestration
- Small-scale plant has proven the concept in Iceland
- https://www.jwnenergy.com/article/2017/10/climeworks-captures-co2-air-turns-it-rock-world-first/

Capture CO_2 in Olivine

Mg_2SiO_4 (olivine) + 2 CO_2 = 2$MgCO_3$ (magnesite) + SiO_2 (quartz)

- Olivine forms 60% to 80% of the Earth's mantle (i.e. it is abundant)
- The products are stable solids and easily stored
- Reaction rates are rapid at 185C
- Process: Frack Olivine deposits, heat to 185C, and pump CO_2 into ground



Capture CO2 in Olivine

Problem

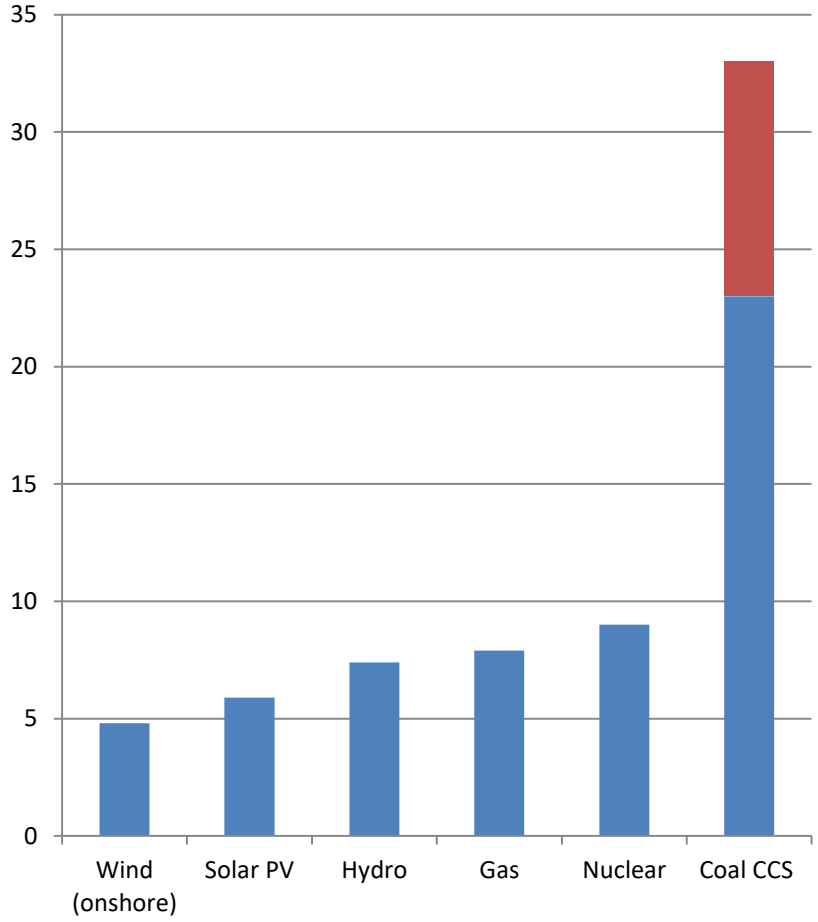
- Climeworks hopes to bring cost down to $100 to $150 / ton of CO_2 by 2025
- This increases the cost of coal
  - $0.02/kWh (current)
  - $0.23/kWh @ $100/ton
  - $0.33/kWh @ $150/ton
- 540lb of coal produce
  - 1 ton of CO_2
  - 486 kWh of electricity
  - $48.6 in revenue at $0.1/kWh
  - $100 to $150 in expenses
- 540lb of coal costs $11
  - $0.02/lb
- ($100 + $11) / 486kWh = $0.23/kWh

Cost Comparison

Source: Energy and Information Administration
https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf

Cents / kWh (2025 est)

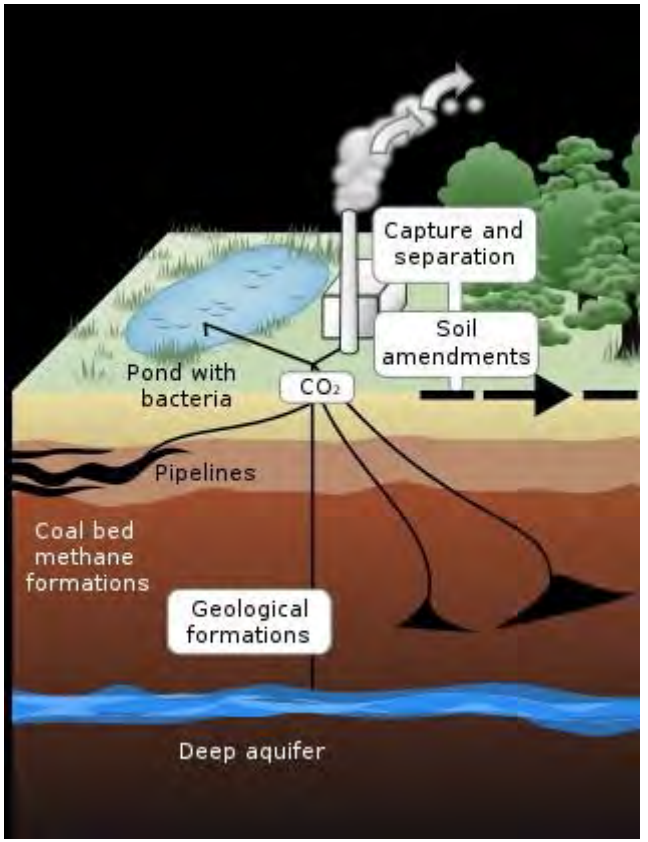
- 4.8: Wind (onshore)
- 5.9: Solar PV
- 7.4: Hydro
- 7.9: Gas
- 9.0: Nuclear
- 23 to 33: Coal CCS



Carbon Capture

Carbon Sequestration Method #4: Idea

- Rather than release CO_2 into the atmosphere, store it underground



Carbon Capture

Problem 1/4

The volume of CO_2 gas is huge:

- Each year, the U.S. produces
  - 2669 million tons of CO_2
  - 1358 billion cubic yards of CO_2
- 1358 billion cubic yards is a huge volume.
  - 100,000 time the largest cave in the world
    - Miao Room, China, 14 million cubic yards
  - About 0.8 ppm of the volume of the Earth's atmosphere

The photographer's lights illuminate the green-hued Getu He river in the Miao Room—the world's largest cave chamber by volume.

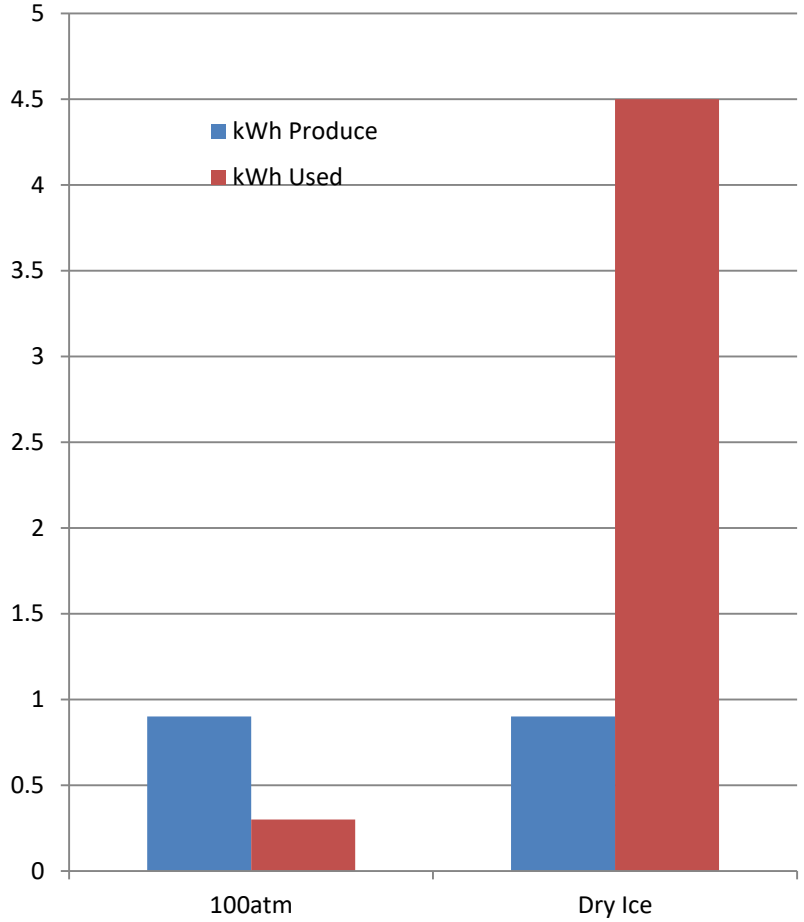
PHOTOGRAPH BY CARSTEN PETER, NATIONAL GEOGRAPHIC

China's "Supercave" Takes Title as World's Most Enormous Cavern

Carbon Capture

Problem 2/4

- If you compress the CO_2, the volume becomes smaller. (good)
- It takes energy to compress CO_2 (bad)
  - 1lb Coal equals
    - 0.9kWh electricity
    - 3.7lb CO_2
  - 3.7lb CO_2 requires
    - 0.3kWh to compress to 100atm (100x less volume)
    - 4.5kWh to turn into dry ice (500x less volume)



Carbon Capture

Problem: 3/4

- The earth leaks: gasses don't remain underground

Carbon Capture

Problem: 4/4

- Requires an enormous amount of money be spent on infrastructure.
- Requires taxpayer to fund clean up costs of coal industry.

Conclusion

- Burning fossil fuels and then trying to put the CO2 back into the ground
  - Either cannot work, or
  - Is cost prohibitive.

What's the Point Behind Clean Coal?

- Confuse the public and politicians
  - Instill doubt
  - Mimic tactics used by the Tobacco industry
- Extend the life of stranded assets
  - Coal
  - Oil

Better Solution

- If you want to produce energy without adding to the atmosphere's CO_2 level, there are better alternatives:
  - Wind
  - Solar
- If you're interested in promoting these schemes, consider joining C.L.E.A.N.