Carbon Capture, Use and Storage/Sequestration - CCUS

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PASSION FOR CHEMISTRY

The Problem

- Combustion of fossil fuels and biomass or the production of steel and cement generates CO_2 and H_2O + Heat which is used to generate steam in thermal fossil fuel power stations or for transport. In a power station, the steam turns a turbine and electricity is generated.
- The Equation is: $C_xH_yO_z + O_2 \rightarrow CO_2 + H_2O$ + Heat (+ N_2 + SOx)
- CO_2 is a powerful green house gas
- When air is used for combustion, N_2 and NOx are also produced in the flue gas.
- If coal that has sulphur in it is used, SOx is also produced

The Solution

- Separate the N_2 from the CO_2 in the flue gas and capture/store/use the CO2. This is known as Post-Combustion CCS.
- Separate O_2 from N_2 in ambient air and use pure O_2 for the combustion reaction then only CO_2 and H_2O is produced. This is called Oxy-Combustion.
- CO_2 can be stored in geological formations
- CO_2 can be used in Enhanced Oil Recovery
- CO_2 can be used as a Carbon source monomer for synthesizing larger molecules
- Reacting CO_2 with NaOH produced Soda Ash or Sodium Carbonate

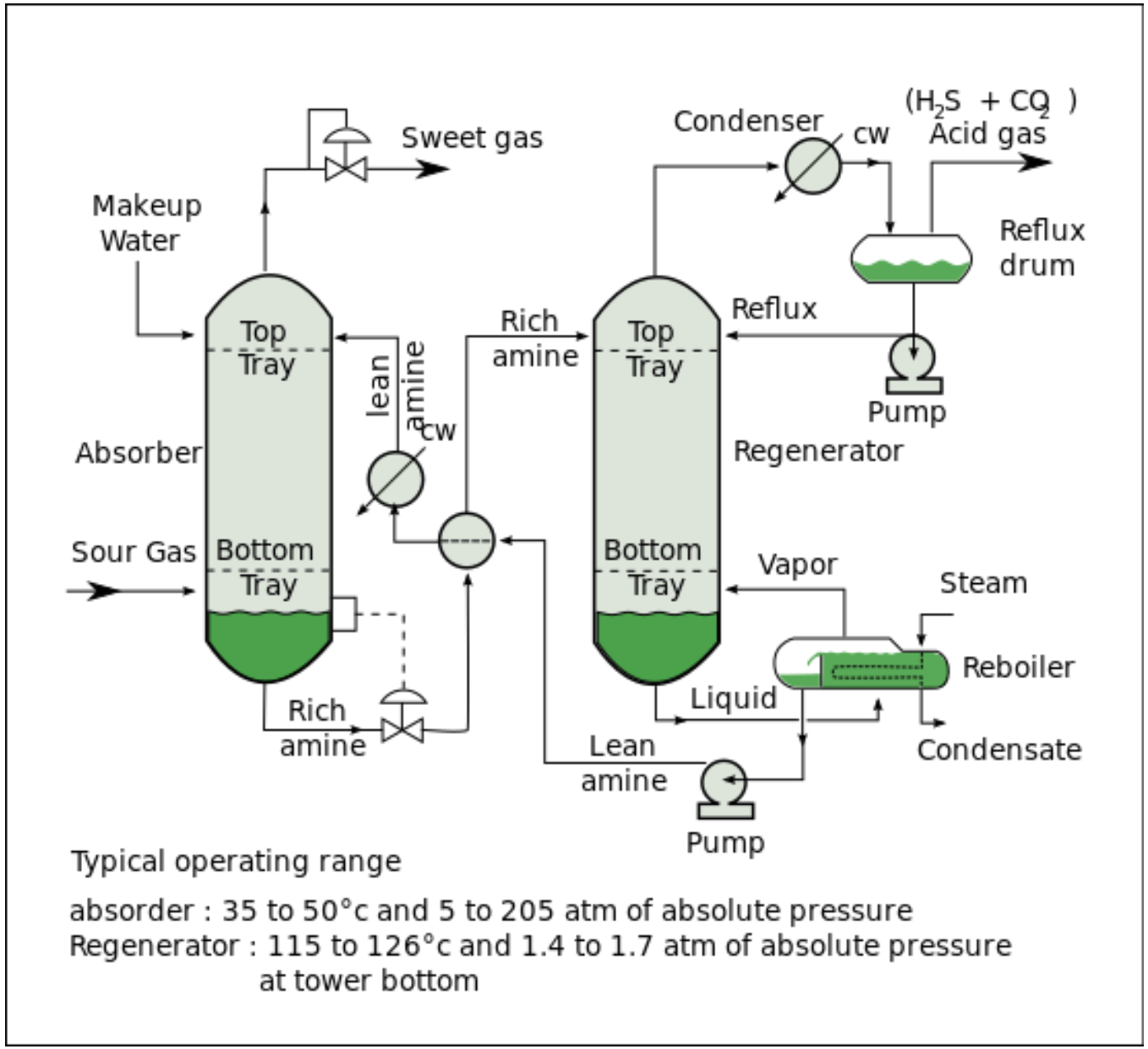
The Chemistry

- Amine gas treating, also known as amine scrubbing, gas sweetening and acid gas removal, refers to a group of processes that use aqueous solutions of various alkylamines (commonly referred to simply as amines) to remove hydrogen sulfide (H2S) and/or carbon dioxide (CO2) from combustion flue gases.
- It is also possible to combust the fossil fuel incompletely to produce CO and H2 called Syngas.
- Calcium looping processes for capturing CO2 from large emissions sources are based on the use of CaO (lime) particles as sorbent in circulating fluidized bed reactors.
- Gas separating membranes are also being proposed that can separate CO2 from N2 and even recover H2O.

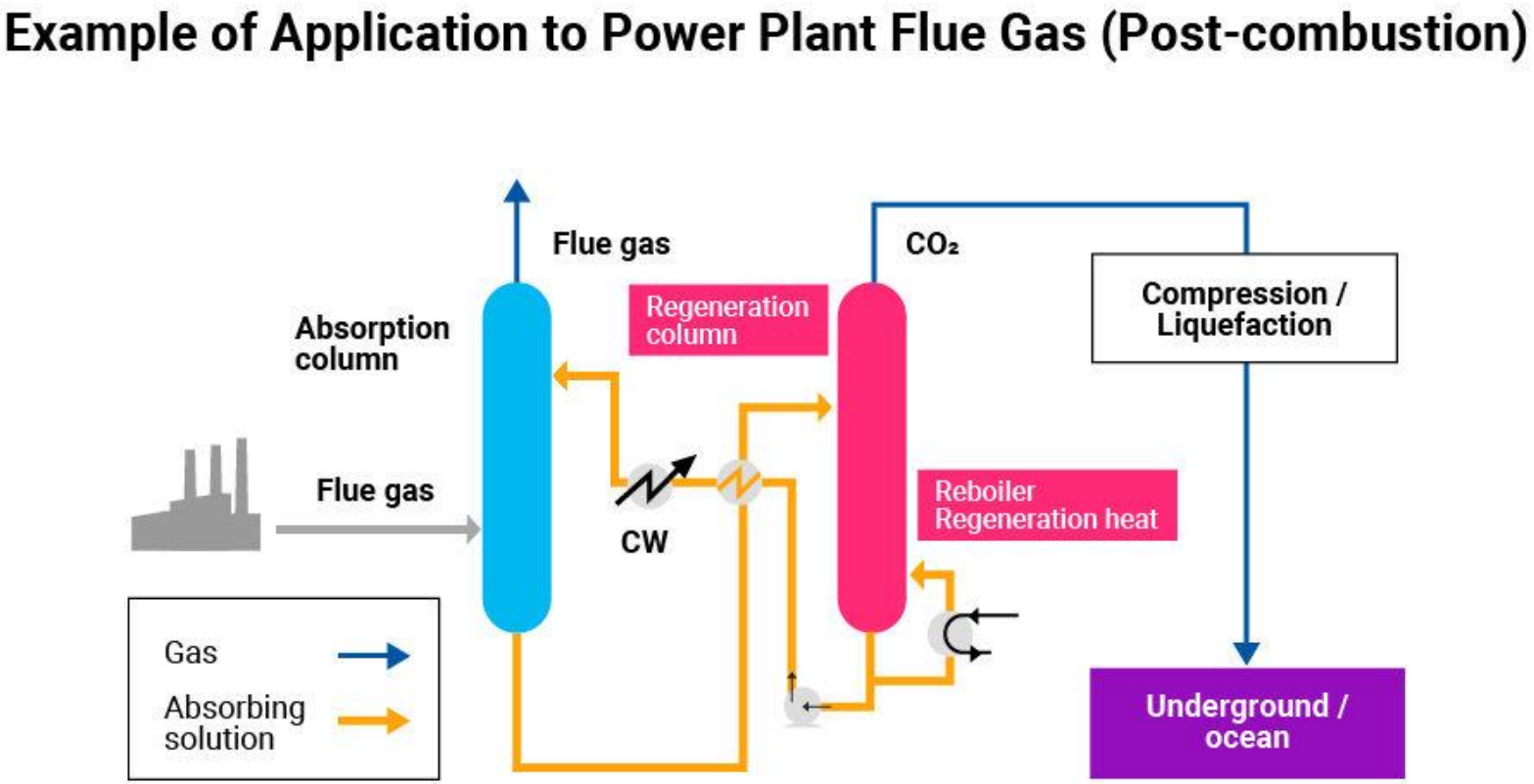
Process Diagram of Amine Absorber >

Animation of CCS from GE Power Below:

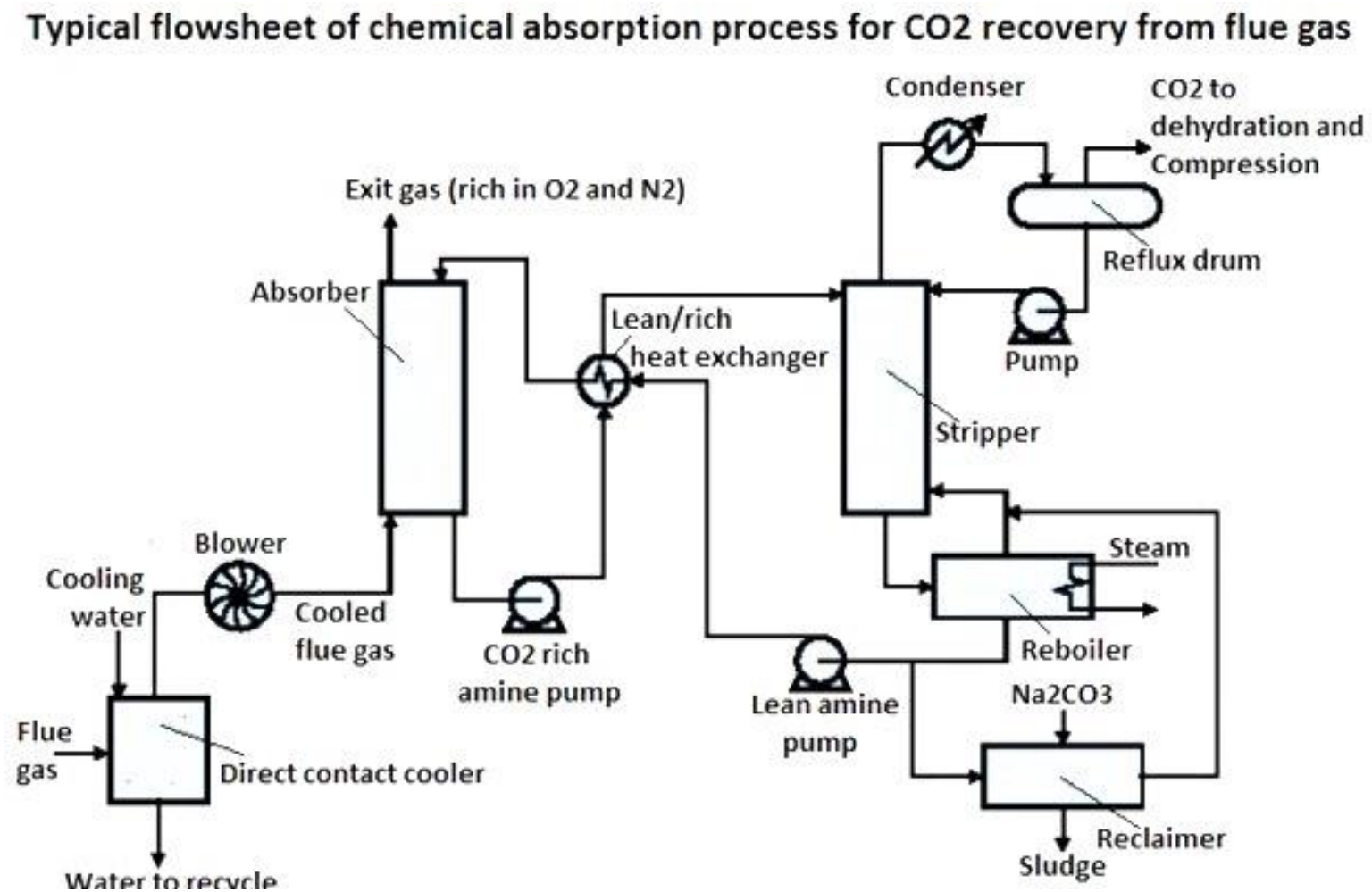
https://www.youtube.com/watch?v=J8IRLH1nuCg



Simplified Process Diagram



Flow Sheet of CCS



Sample Video about CCS

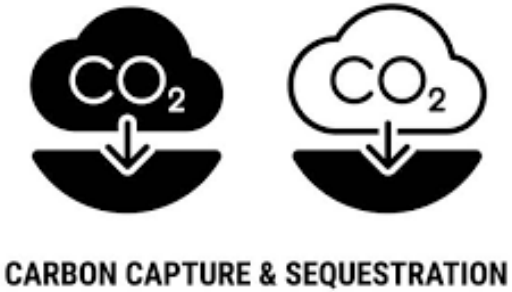
- https://www.youtube.com/watch?v=EyPI20h9kx0
- Video by Shell:

  https://www.youtube.com/watch?v=3aIWojhj7Xo
- Video from GE

  https://www.ge.com/gas-power/future-of-energy/carbon-capture-storage

Costs: CAPEX and OPEX

- CAPEX cost for the installation of the system
- OPEX costs in terms of chemicals used, water and power to power the absorber pumps, blowers, cooling towers, steam generation and the CO2 compressors.



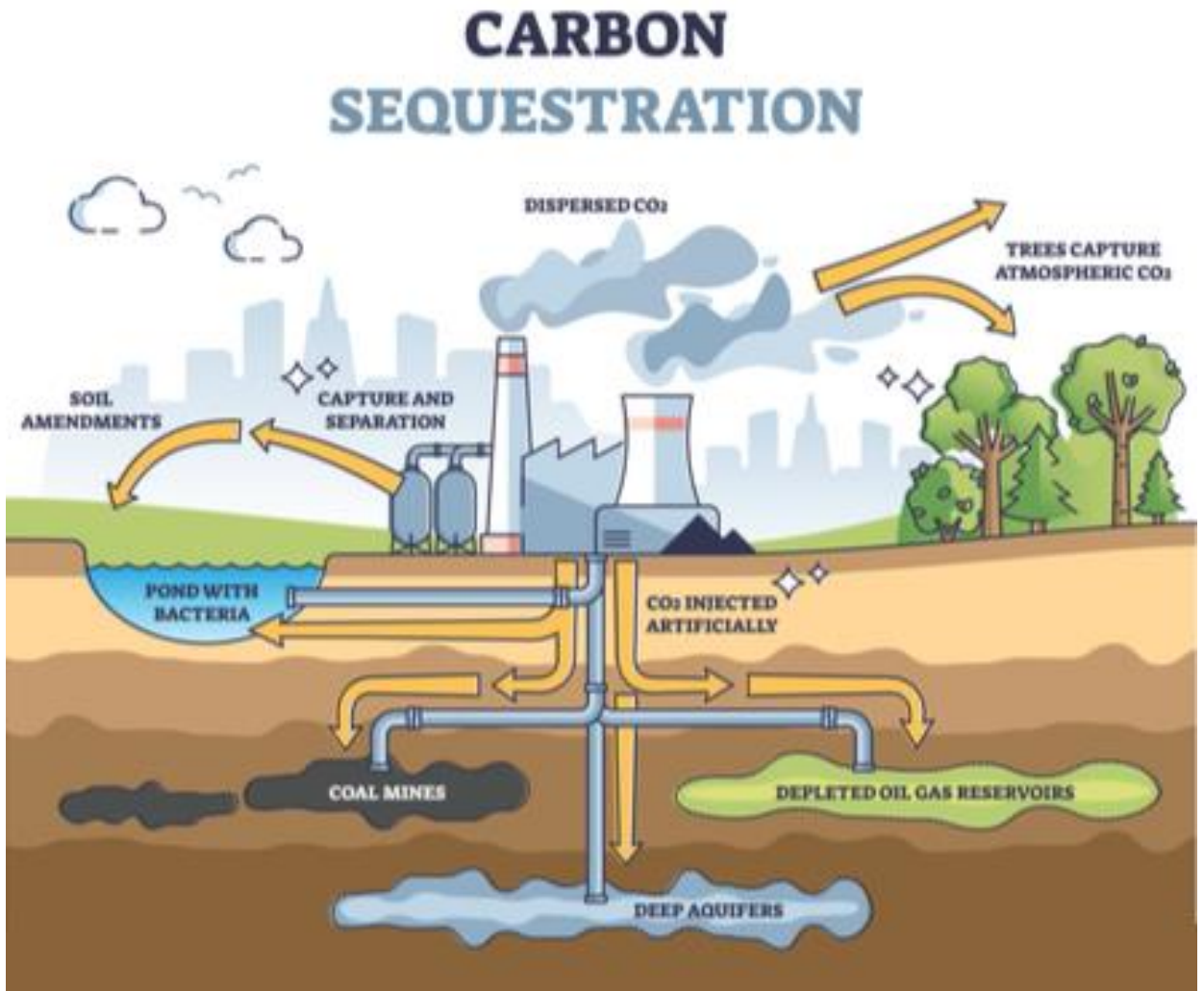
Uses of CO_2

- CO_2 is a non-polar acidic gas
- It can be used to decrease the pH or neutralize alkaline waters
- If CO_2 is reduced to CO it can be used a monomer building block
- Labs around the world are trying to synthesize bio-plastics out of CO_2
- Plants/Trees turn CO_2 and Water into Lignin and Cellulose
- Farms can use CO_2 as a fertilizer/agro-stimulant in green houses
- CO_2 is used in soft drinks
- CO_2 is injected at a low dose in aquariums to feed the plants/algae
- CO_2 gas can be used to enhance oil recovery by pressurising oil formations

Capture of CO2 Using Micro-Organisms

- https://www.theguardian.com/environment/2023/apr/19/volcanic-microbe-eats-co2-astonishingly-quickly-say-scientists

CO2 Sequestration Diagram



Sequestration Geological Locations

- Sedimentary rocks are suitable for the storage of CO2 due to their frequent high values of porosity and permeability.
- Depleted oil and gas reservoirs, unmined coal beds and saline geological formations are also suitable.
- Basalt formations typically have a composition of 45–52 wt% SiO2, 2–5 wt% total alkalis, 0.5–2.0 wt% TiO2, 5–14 wt% FeO and 14 wt% or more Al2O3. Contents of CaO are commonly near 10 wt%, those of MgO commonly in the range 5 to 12 wt%. The latter reacts with CO2 to form carbonates.

Pioneers

- GE Power/ALSTOM
- Shell
- ARAMCO
- INEOS
- Linde Engineering
- Scrubbing Agents from BASF
- Occidental Petroleum

Real Life CCS Projects

- China's largest carbon capture and storage plant at Guohua Jinjie coal power station was completed in January 2021. The project is expected to prevent 150,000 tons of carbon dioxide emission annually at a 90% capture rate.
- In 2020, Norway announced "Longship" ("Langskip" in Norwegian). This 2,7 billion CCS project will capture and store the carbon emissions of Norcem's cement factory in Brevik.
- After the success of their pilot plant operation in November 2011, the Abu Dhabi National Oil Company and Abu Dhabi Future Energy Company moved to create the first commercial CCS facility in the iron and steel industry.[55] CO2 is a byproduct of the iron making process. It is transported via a 50 km pipeline to Abu Dhabi National Oil Company oil reserves for EOR. The facility's capacity is 800,000 tonnes per year. As of 2013, more than 40% of gas emitted by the crude oil production process is recovered within the oil fields for EOR.

References

- https://en.wikipedia.org/wiki/List_of_carbon_capture_and_storage_projects
- https://en.wikipedia.org/wiki/Carbon_capture_and_storage
- https://www.ge.com/gas-power/future-of-energy/carbon-capture-storage