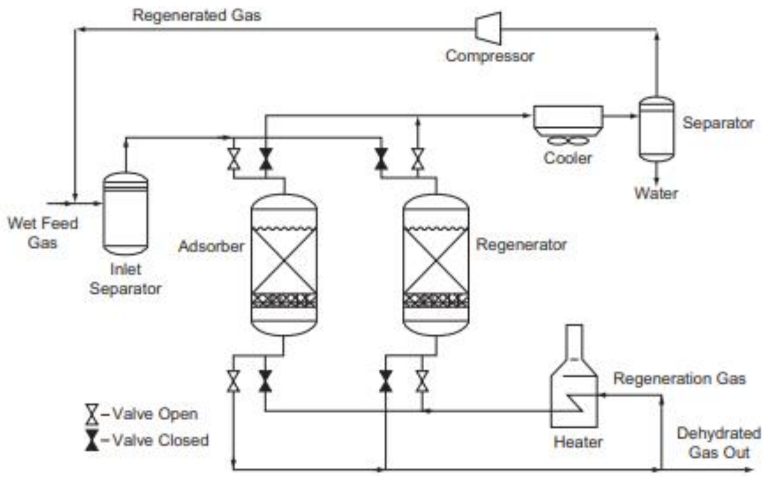
ADSORPTION-BASED DEHYDRATION

map-it CCU

Adsorption-based methods for dehydration involve using solid sorbents (molecular sieves/silica/zeolites/alumina) to capture and remove moisture from gas streams. These methods are efficient and have been optimized for industrial applications, offering high recovery rates and cost-effectiveness. Advances in materials science have led to the development of more selective and efficient adsorbents, making adsorption a viable option for **dehydrating the flue gas stream**. For continuous operation, two reactors are used, alternating between adsorption and regeneration modes. Sorbents can be regenerated either by increasing the temperature (temperature swing) or reducing the pressure (pressure swing). Generally, heated air or regenerated gas is passed through the adsorption bed for regeneration.



Dehydration by adsorption process.

REMOVED COMPONENTS

- Water (H_2O) is the primary target component.

FUNCTION IN CCU VALUE CHAIN

- Reduction of H_2O content in flue gases.
- Prevent corrosion and fouling of equipment.
- Water, along with H_2S in CO_2 streams, can form corrosive acids that severely damage pipes and valves.
- Improving the efficiency and longevity of CO_2 capture systems.

LIMITATIONS

- The adsorption capacity (wt.%), the final water concentration (ppmv), and the regeneration temperature of the main desiccants are as follows[1,2]:
  - Silica gel: 6-7 wt.% / 10 ppmv / 120-130 °C
  - Molecular sieves: 8-10 wt.% / 1 ppmv / 175-320 °C
  - Activated alumina: 4-5 wt.% / 5 ppmv / 175-250 °C
- The adsorption and regeneration processes are highly sensitive to temperature variations.
- Adsorbent degradation due to multiple regeneration cycles.

ENERGY

- Heat is primarily used for regeneration.
- Electricity is mainly used for compressors and blowers if needed.

CONSUMABLES

- Adsorbent materials, though not consumed, may need replacement due to degradation.

Energy & consumables

Parameter	Value
Electricity (kWh/kgH_2O)	0.15[3]
Heat (kWh/kgH_2O)	1.2[3]
Cooling duty (kWh/kgH_2O)	2.0[3]

Values are based on per kg of H_2O removed.
[3]Flue gas dehydration with 11.64% CO_2 and 2.96% H_2O; adsorbent - silica gel; regeneration temp. – 150 °C; cooling temp. – 30 °C; cooling duty can be used to estimate the cooling water.

COSTS

The costs of adsorption-based dehydration systems can vary widely depending on factors such as the type of adsorbent used, the scale of operation, the energy costs, and the technology's maturity.

<u>Flue gas dehydration costs</u>

CAPEX: ~5.2 €/tCO_2[3]

OPEX: ~3.1 €/tCO_2[3]

Total cost: ~8.3 €/tCO_2[3]

[3]Flue gas dehydration with 11.64% CO_2 and 2.96% H_2O; adsorbent - silica gel; regeneration temp. – 150 °C; cooling temp. – 30 °C; H_2O limit – 100 ppm; CRF – 0.154; 8000 hr/yr; 2019 euros; electricity price – 62.5 €/MWh; steam price – 5.4 €/t; 5000 t/d flue gas.

**Please note that these costs are rough calculations based on the available data. These costs can be* *converted per ton of H_2O by multiplying the costs by the amount of water per ton of CO_2 in the flue gas stream.*

TECHNOLOGY PROVIDERS

- SILDRY® by **Silica**, Germany (Gas and CO_2 dehydration)
- Gas dryers by **Delair™**, Netherlands.
- Gas dehydration by **NOV,** Scotland
- Gas dehydration by **Axens**, France

ALTERNATIVE TECHNOLOGIES

- **Absorption process**: Water vapor is absorbed into a liquid desiccant, such as triethylene glycol (TEG). The saturated desiccant is then regenerated by heating to remove water.[4] TEG dehydration systems are capable of reducing water content in gas streams up to 50 ppmv.[5]
  Glycol dehydration by **SLB**, USA
  Glycol dehydration by **NOV**, Scotland
- **Refrigeration and Condensation**, where the gas stream is cooled to very low temperatures to condense and remove water as liquid or solid (ice).[1]
- **Membrane separation** is where specialized membranes selectively permeate water vapor while retaining CO_2. Air Liquide offers natural gas dehydration units [6]. The same process can be used for flue gas dehydration.

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REFERENCES

1. Abbas Z, Mezher T, Abu-Zahra MRM. CO2 purification. Part I: Purification requirement review and the selection of impurities deep removal technologies. *Int J Greenh Gas Control*. 2013;16:324-334.
2. IEAGHG. *Evaluation and Analysis of the Performance of Dehydration Units for CO2 Capture*. Vol 04.; 2014. https://ieaghg.org/publications/evaluation-and-analysis-of-the-performance-of-dehydration-units-for-co2-capture/
3. Zanco SE, Pérez-Calvo JF, Gasós A, Cordiano B, Becattini V, Mazzotti M. Postcombustion CO2 Capture: A Comparative Techno-Economic Assessment of Three Technologies Using a Solvent, an Adsorbent, and a Membrane. *ACS Eng Au*. 2021;1(1):50-72.
4. Øi LE, Nitsche P, Aromada S. Comparison of Absorption and Adsorption Processes for CO2 Dehydration. *Proc First SIMS EUROSIM Conf Model Simulation, SIMS EUROSIM 2021, 62nd Int Conf Scand Simul Soc SIMS 2021, Sept 21-23, Virtual Conf Finl*. 2022;185(September):287-292.
5. NOV. *CO2 Dehydration Product Offerings*.; 2024. https://www.nov.com/-/media/nov/files/capabilities/carbon-capture-utilization-and-storage-solutions/co2-dehydration-product-offerings-brochure.pdf
6. Air Liquide. *Membrane Units for Natural Gas Dehydration*.; 2024.

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