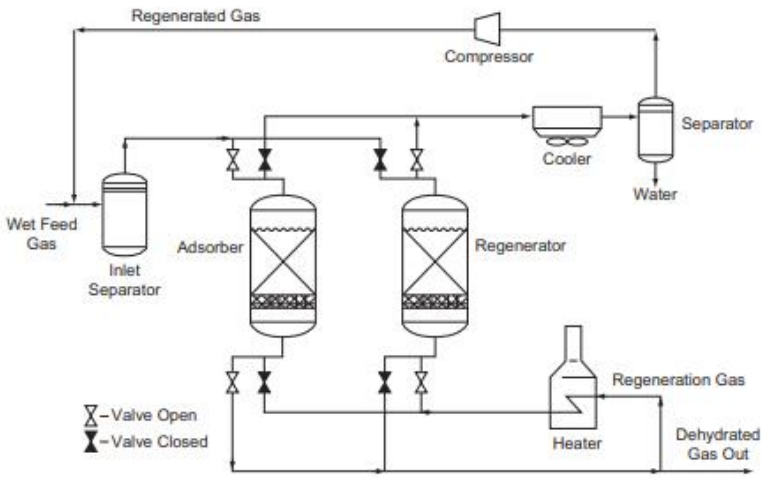
ADSORPTION-BASED DEHYDRATION

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 both flue gas (pretreatment) and captured CO_2 stream (purification)**. 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
  - Sorbead® (BASF): < 5 ppmv[3]/ 170 °C [4](specially for CO_2 dehydration)
- 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[5]
Heat (kWh/kgH_2O)	1.2[5]
Cooling duty (kWh/kgH_2O)	2.0[5]

Values are based on per kg of H_2O removed.
[5]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.

Flue gas dehydration costs

CAPEX: ~5.2 €/tCO_2[5]
OPEX: ~3.1 €/tCO_2[5]
Total cost: ~8.3 €/tCO_2[5]
[5]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.

CO_2 dehydration costs

CAPEX: 0.09 – 0.18 €/tCO_2[4]

OPEX: 0.60 – 1.21 €/tCO_2[4]

Total cost: 0.69 – 1.38 €/tCO_2[4]

[4]*Lower range values for Sorbead sorbent; lifetime – 5-10 yrs; plant lifetime – 30 yrs; 2.5 MTPA CO_2; regeneration temperature – 160-170°C; H_2O limit – 30 ppmv; energy cost – 120 €/MWh.*

[4]*Upper range values for activated alumina sorbent; lifetime – 3 yrs; plant lifetime – 30 yrs; 2.5 MTPA CO_2; regeneration temperature – 220-250°C; H_2O limit – 30 ppmv; energy cost – 120 €/MWh.*

**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 captured CO_2 stream.*

TECHNOLOGY PROVIDERS

- SILDRY® by Silica, Germany (Gas and CO_2 dehydration)
- Sorbead® for CCS by **BASF**, Germany (CO_2 dehydration)
- EVERDRY® by **Beko Technologies**, Germany (CO_2 dryers)
- CO_2 dryers by **ATLAS-COPCO**, Sweden (not mentioned on the website)
- 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.[6] TEG dehydration systems are capable of reducing water content in gas streams up to 50 ppmv.[7]
  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 [8]. The same process can be used for CO_2 dehydration.

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