The Case for Cryogenic CO_2 Capture

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CO_2 Capture Technologies

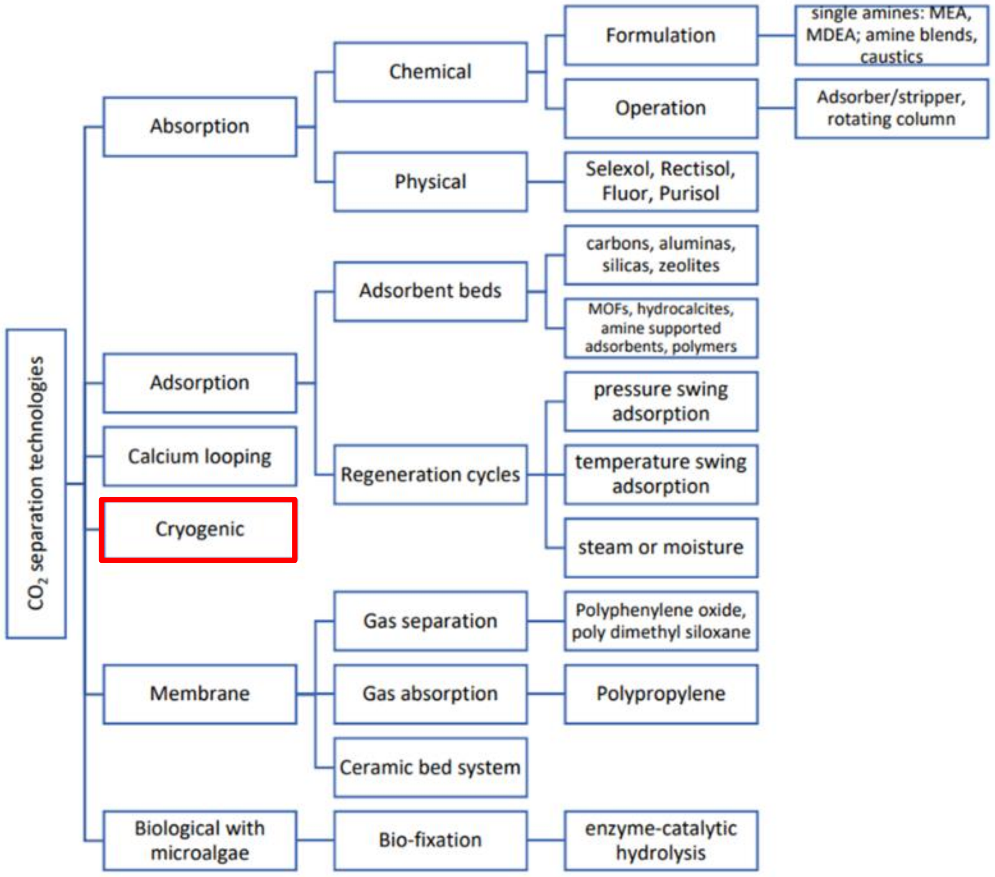
Absorption and Adsorption based technologies are commercially available but have drawbacks including:

- High capital cost
- High water usage
- Large footprint

Alternatives including cryogenic capture require continued R&D funding to mature and potentially overtake established methods

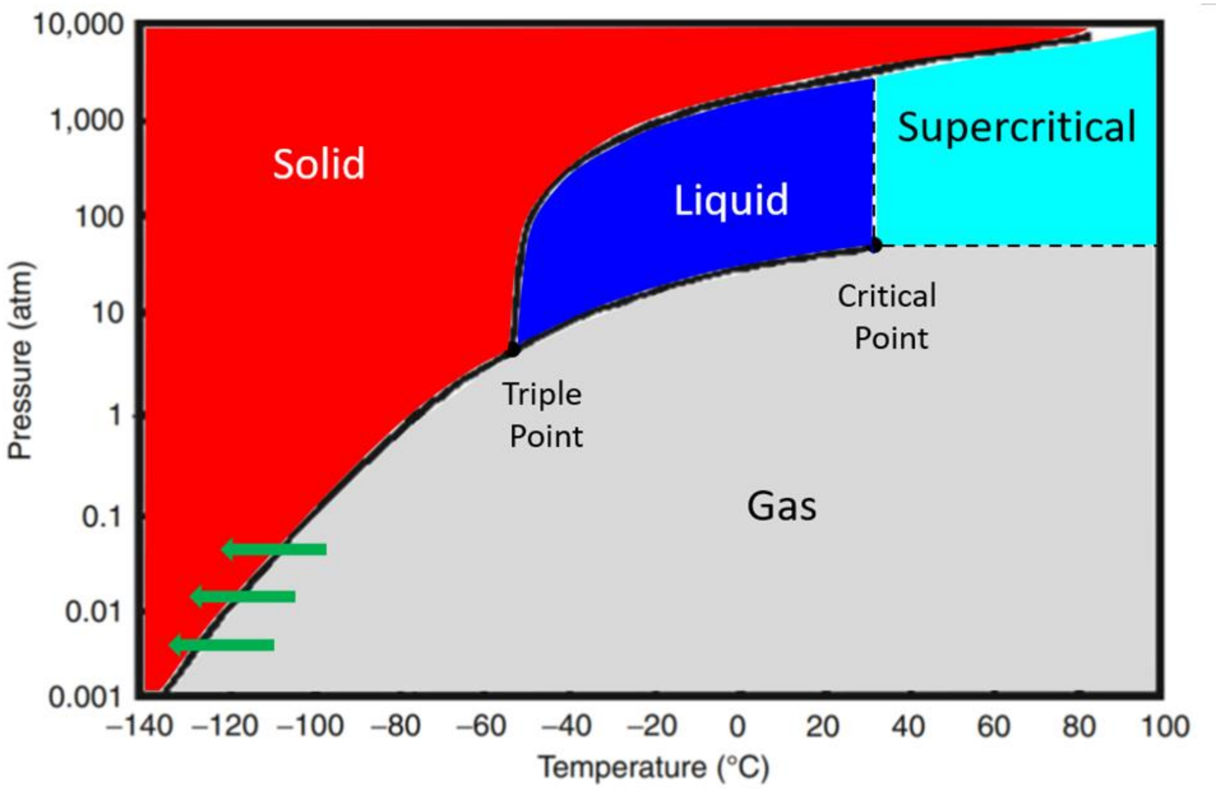
Cryogenic separation has the benefit of using technologies familiar to power plant operators

- Turbomachinery (compressors and turbines)
- Heat Exchangers



Font-Palma, C., Cann, D., Udemu, C., 2021, "Review of Cryogenic Carbon Capture Innovations and Their Potential Applications," C Journal of Carbon Research, 7, 58.

How Does Cryogenic CO_2 Capture Work?



Pressure-temperature phase diagram for CO_2

Partial pressure of CO_2 in exhaust gas is well below Triple Point pressure

In this region, CO_2 condenses by 'desublimation' going directly from gas to solid

As CO_2 condenses, the concentration of CO_2 in the exhaust gas decreases requiring lower and lower temperatures for additional condensation (green arrows)

Two Ways to Cool a Fluid

Heat Transfer

Energy is removed from the fluid by heat transfer across a boundary

Boundary surface area determines rate

Requires a temperature gradient to drive the heat transfer process

Boundary must be colder than the stream

Freezing solids accrete on the cold boundary surfaces

Work Extraction

Energy is removed from the fluid by extracting work through a moving boundary

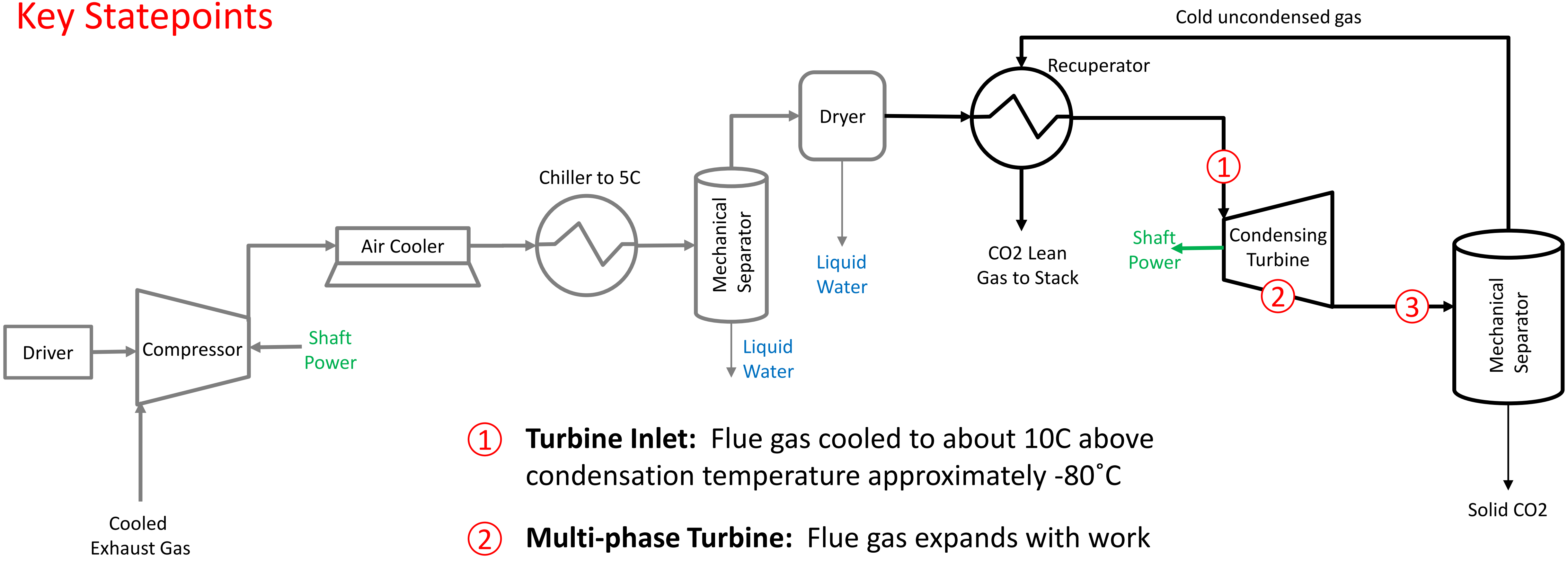
Volumetric effect, not dependent on boundary surfaces

Moving boundary can be positive displacement (piston/cylinder) or dynamic (turbine)

Fluid can be cooled via work extraction even when the boundary surfaces are warmer than the fluid – eliminates accretion.

Basic Turbomachinery Based Process

Key Statepoints



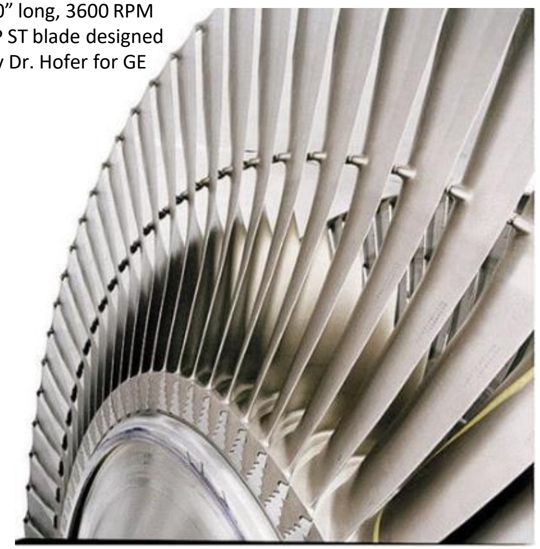
① **Turbine Inlet:** Flue gas cooled to about 10C above condensation temperature approximately -80˚C

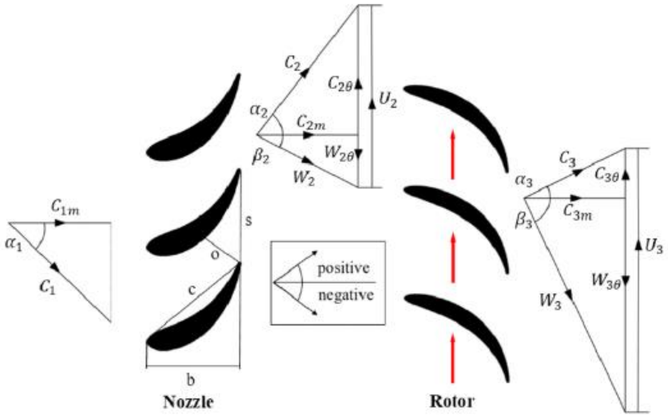
② **Multi-phase Turbine:** Flue gas expands with work extraction lowering enthalpy and temperature

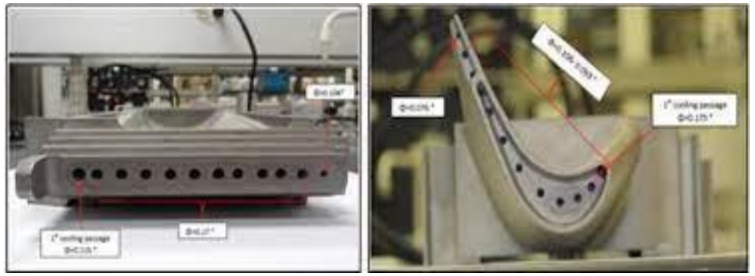
③ **Turbine Exit:** Cooled flue gas and condensed solid CO_2 exit turbine at approximately -120˚C

Key Advantage – Condensing Turbine

40” long, 3600 RPM
LP ST blade designed
by Dr. Hofer for GE







LP Steam Turbines have homogeneous condensation of up to 12% liquid

CO_2 condensation differs:

- Solid condensate
- Phases closer in density

Work extraction in turbine lowers enthalpy (cools) via work extraction – not surface heat transfer

Airfoil surfaces can be warmed with internal gas flow to avoid dry ice buildup – reverse of cooled gas turbine blades

These features combine to break the paradox of how to cool flow without buildup of CO_2 ice on surfaces

Turbomachinery based Cryogenic CO_2 Capture

- Potential for lower LCOE relative to Amine and oxy-fuel systems
- Solves paradox of cooling without solid CO_2 accretion
- Captures CO_2 with **no** chemicals and **no** consumables
- Inherently Scalable
- All equipment (turbomachinery, heat exchangers) is familiar to power plant operators
- Novel CO_2 condensing turbine opens new solution space

Contact

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