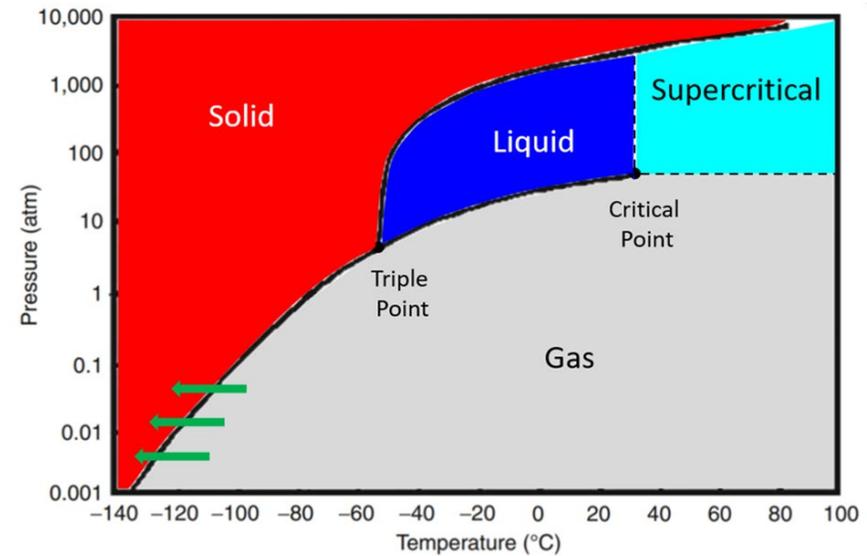
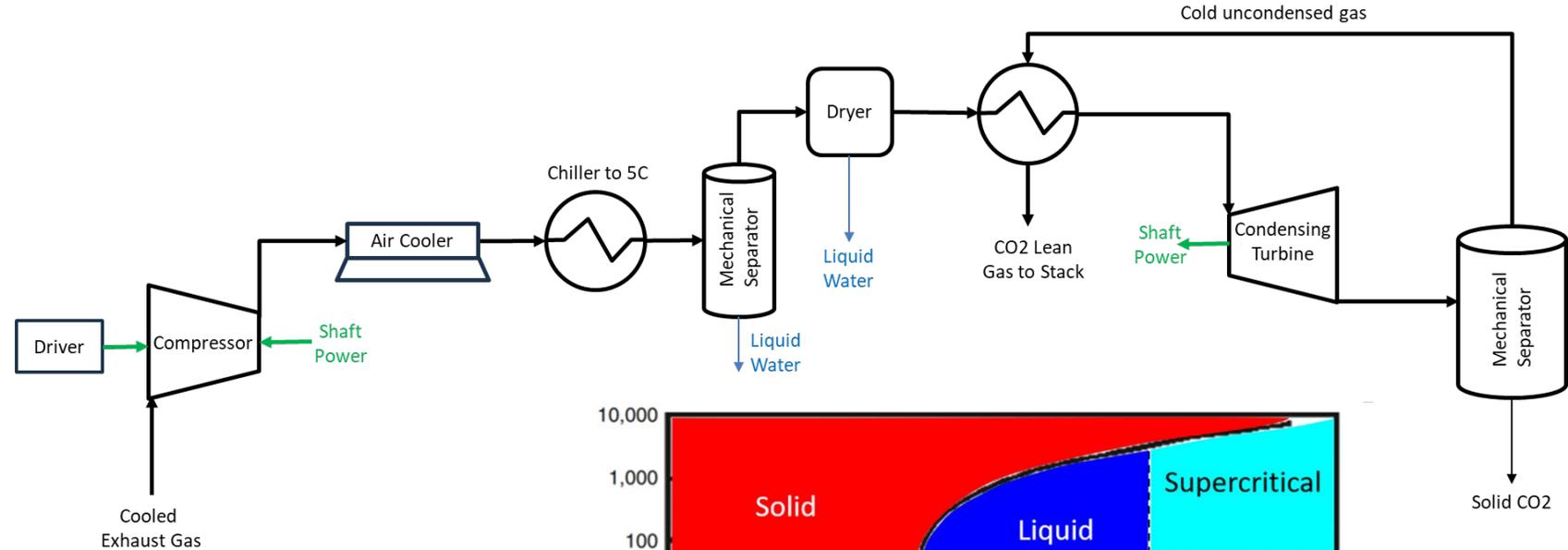


ECCE - Expander Cryogenic Carbon Capture

Owen Pryor, Ph.D.

Senior Research Engineer
RMD - Aero Thermal Modeling and Testing
Machinery Department
Southwest Research Institute

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Pressure-temperature phase diagram for CO₂

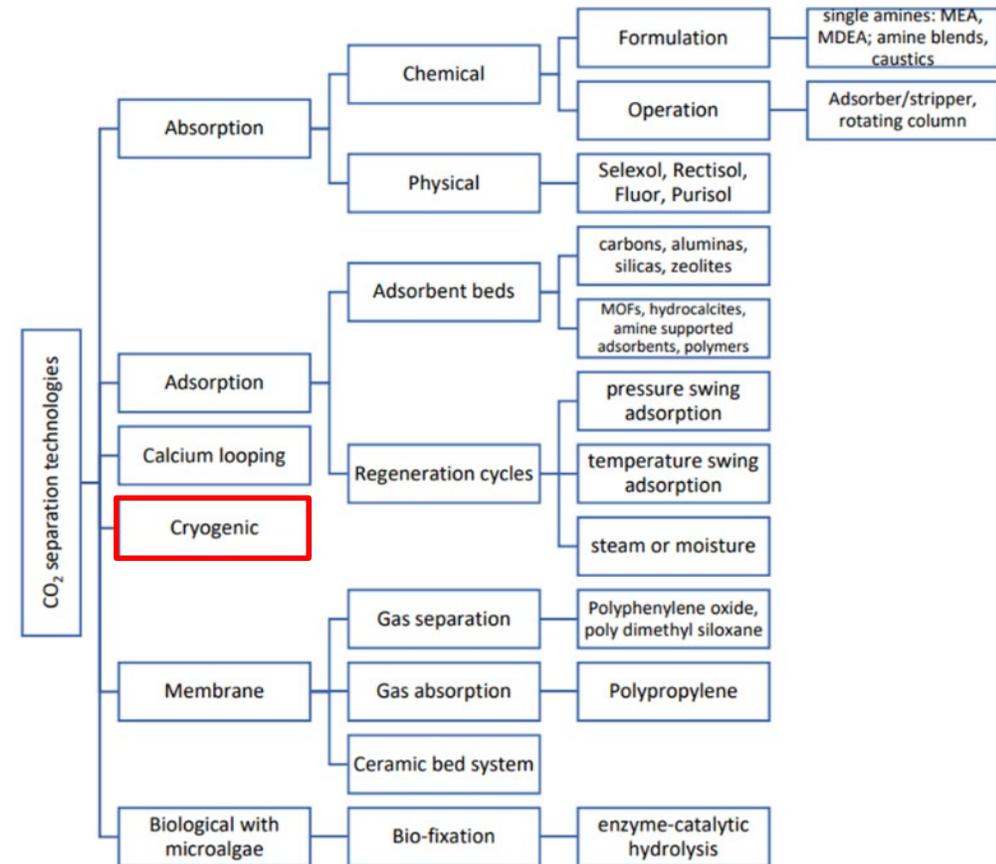


CO₂ capture technologies

Cryogenic Capture is one of several technologies for separating CO₂ from flue gas

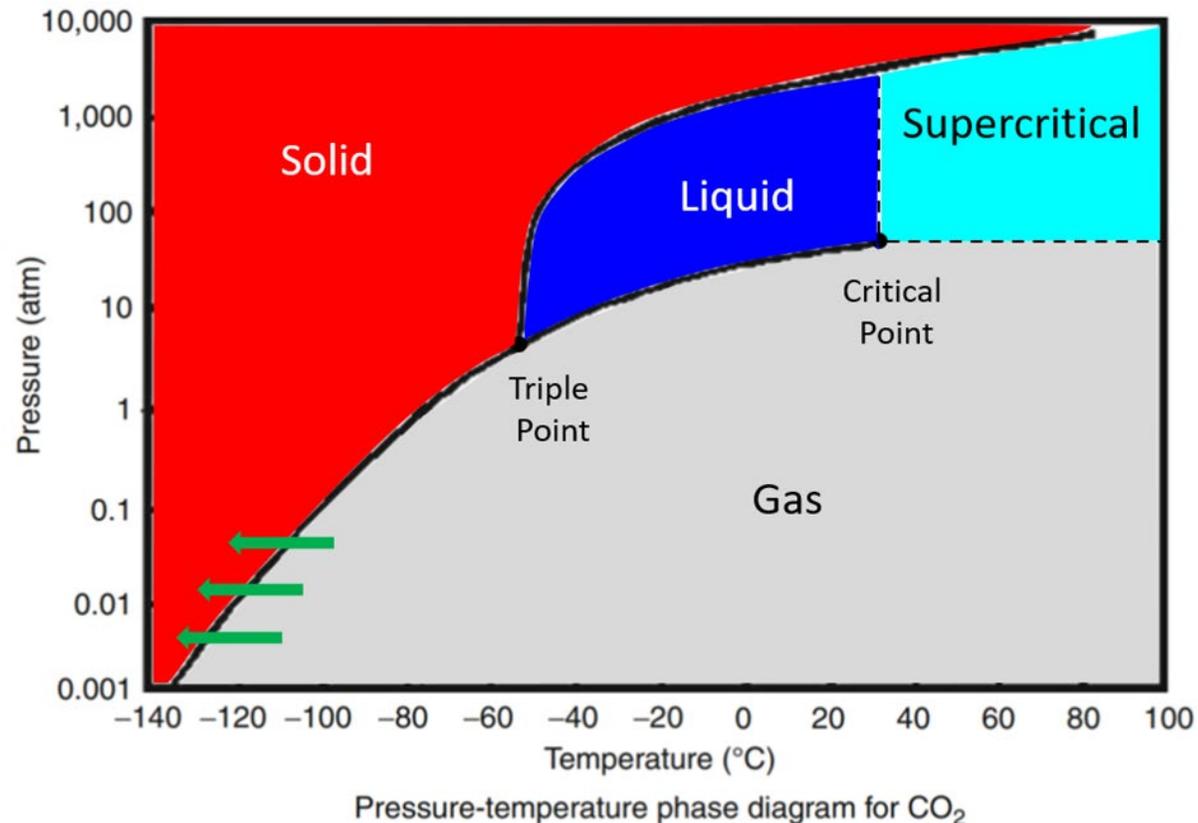
Cryogenic separation has the benefit of using technologies familiar to power plant operators

- 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 CO₂ capture work?

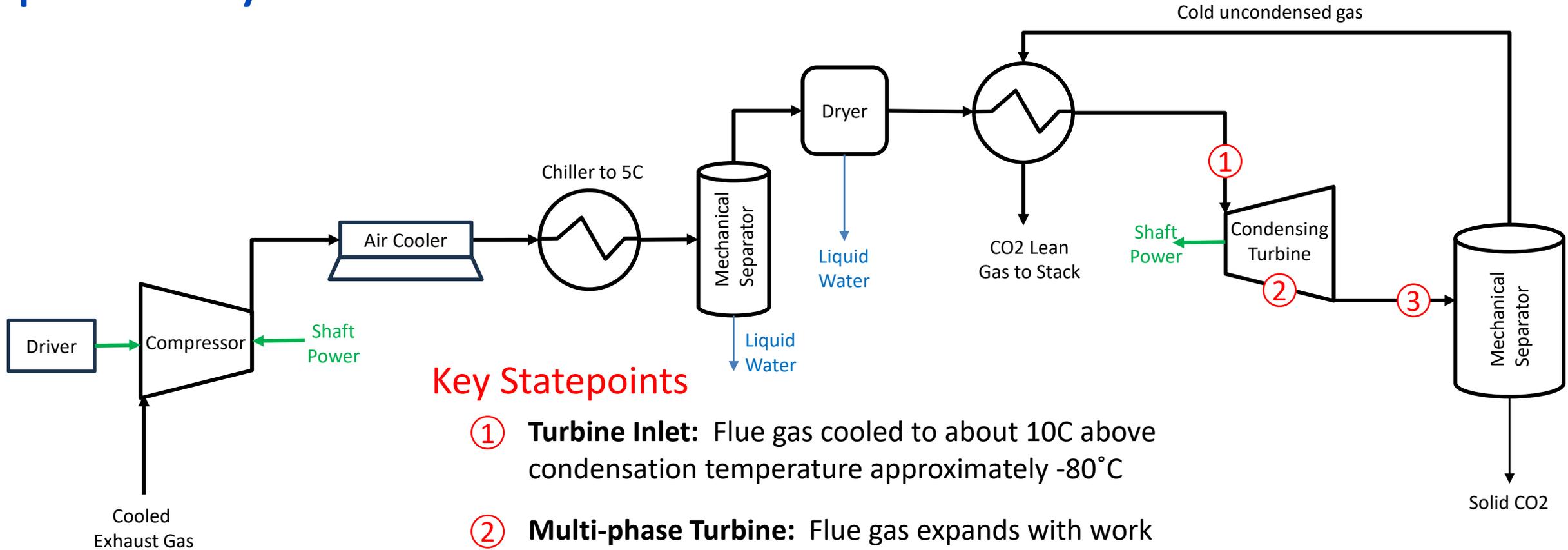


Partial pressure of CO₂ in exhaust gas is well below Triple Point pressure

In this region, CO₂ condenses by 'desublimation' going directly from gas to solid

As CO₂ condenses, the concentration of CO₂ in the exhaust gas decreases requiring lower and lower temperatures for additional condensation (green arrows)

Turbomachinery-based process similar to existing power systems



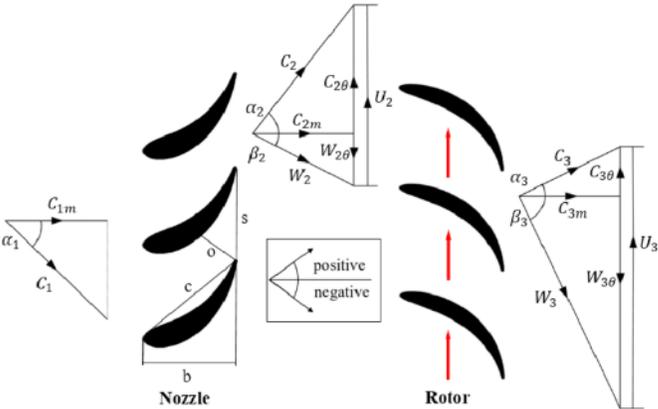
Key Statepoints

- 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

ECCC has several advantages over other technologies

Condensing Turbine

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



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

Able to cool flow without buildup of CO2 ice on surfaces

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

- CO2 condensation differs:
- Solid condensate
 - Phases closer in density



Scalability



<https://www.dw.com/en/siemens-model-company-and-global-player/a-36742363>



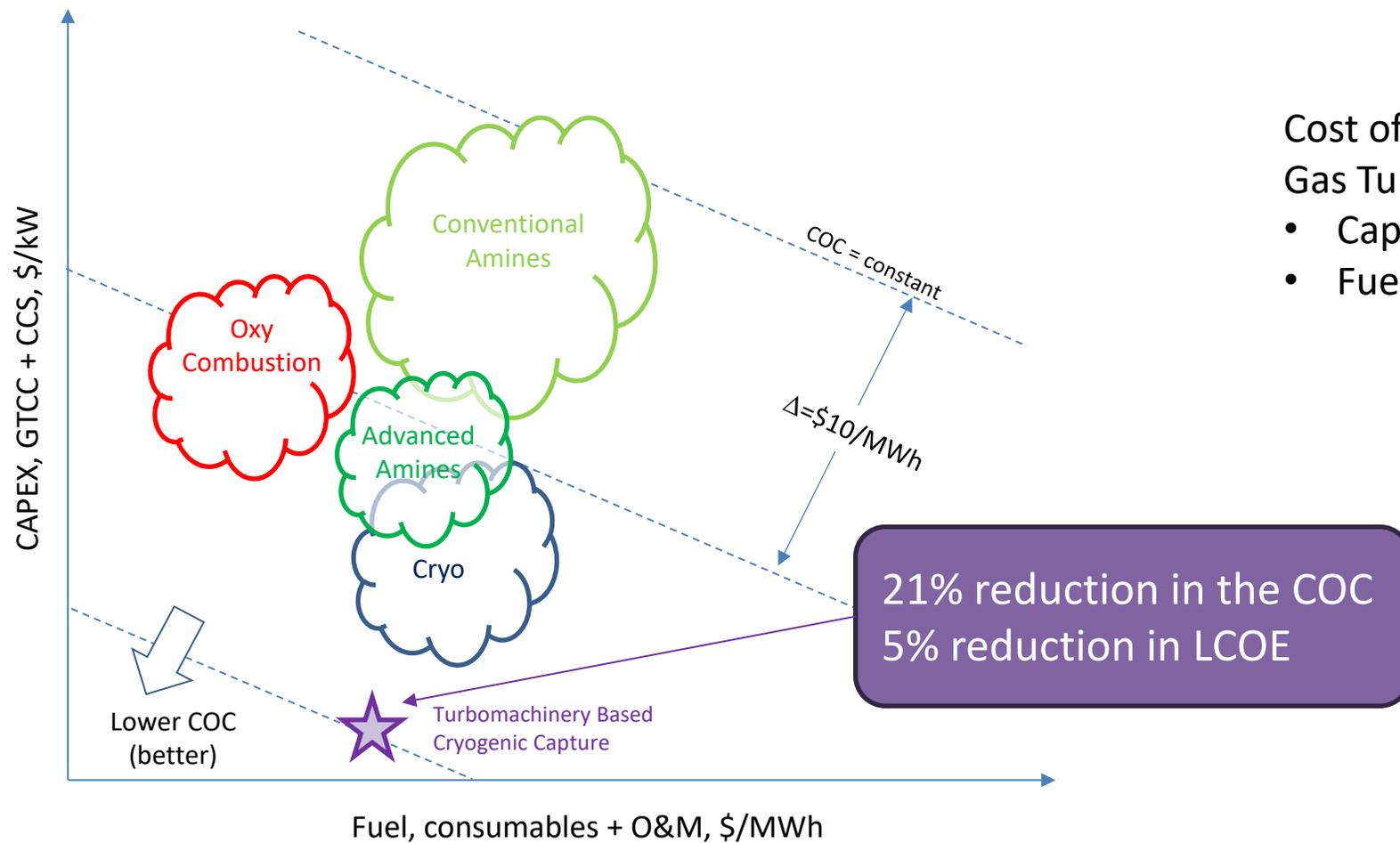
<https://mpnboilers.com/product/modular-hrsg/>

similar volume flow to combustion air in the power generation equipment

Recuperative Heat Exchanger has duty ~50% of HRSG

Equipment available at commercially available scales

Current estimates show that the ECCC has cost advantages



Cost of CO₂ Capture, COC, for a Natural Gas fired Gas Turbine Combined Cycle is influenced by:

- Capital cost of equipment
- Fuel costs & O&M costs

Current and future research plan

SwRI Funded IR&D

- Optimized overall cycle
- Established performance baselines
- Completed turbine feasibility
- Techno-economic comparisons

Completed

Initial Demo

- 1-2 MW engine
 - Radial turbomachinery
 - Leverage turbochargers
- \$3-5 MM
24 Months

DOE / Partners

Large Scale Demo

- 10+ MW engine
 - Axial turbomachinery
 - Bespoke machinery
- \$10+ MM
36 Months

DOE / Partners

The unique capabilities of the ECCC expand carbon capture technologies

- Potential for lower LCOE relative to Amine and oxy-fuel systems
- Solves paradox of cooling without solid CO₂ accretion
- Captures CO₂ with **no** chemicals and **no** consumables
- Inherently Scalable
- All equipment (turbomachinery, heat exchangers) is familiar to power plant operators
- Novel CO₂ condensing turbine opens new solution space

Contact

Owen Pryor

Senior Research Engineer

Aero Thermal Modeling and Testing

Rotating Machinery Dynamics

Machinery Department

Southwest Research Institute

Owen.pryor@swri.org

+1 210 522 4224

