Comparing Low Pressure CO_2–Water Hydro Accumulators and Supercritical CO_2 Turbines for Power Generation

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An assessment of using low pressure CO_2 to pressurize water for hydro turbine generation compared to supercritical CO_2 turbine systems. Learn the design principles, efficiency trade-offs, and applications for each approach.

This webpage QR code

PDF Version of the webpage (maximum 10 pages)

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Introduction

Supercritical CO_2 (sCO_2) turbine systems are widely studied for waste heat recovery and next-generation power cycles due to their very high energy density and efficiency. However, the need for extreme pressures, typically 100 to 200 bar, raises cost and complexity. An alternative approach is to use CO_2 at moderate pressures as a “gas piston” to pressurize water, which then drives a conventional hydro turbine. This article examines how the two approaches differ in design and efficiency, and where each is best suited.

The CO_2–Water Hydro Accumulator Concept

Instead of running CO_2 through a high speed turbine, the gas is stored in pressure vessels separated from water by bladders or pistons. When the CO_2 is compressed or heated, pressure builds and displaces the water side. By opening the water outlet to a hydro turbine, steady pressure and flow are produced without requiring ultrafast turbomachinery.

Key design elements:

Pressure range: typically 3 to 15 bar (low compared to sCO_2).
Water head produced: 30 to 150 meters, depending on charge pressure.
Cycle: two accumulators alternate between charging and discharging for continuous flow.
Advantages: safe pressures, proven hydro turbine technology, easier scaling.
Limitations: modest energy density, large tank volume required for multi-MWh output.

Why CO_2 and Water Must Be Separated

Direct mixing of CO_2 and water dissolves CO_2 into carbonic acid, causing corrosion and loss of pressure. Instead, a physical barrier such as a bladder or piston ensures that gas and liquid do not contact, preserving cycle efficiency and equipment longevity.

Expected Efficiency of the CO_2–Water Hydro Approach

Isothermal expansion losses: efficiency depends on how well the CO_2 side can exchange heat during expansion.
Round-trip electrical efficiency: about 30 to 60 percent when mechanically compressed; higher if waste heat is used for charging.
Scaling constraint: requires large tanks; for example, 10 m^3 of CO_2 expanding from 15 bar to 10 bar yields only ~1.7 kWh.

Supercritical CO_2 Turbine Systems

Supercritical CO_2 cycles operate above 73 bar and 31 °C, with common operating pressures of 100 to 200 bar. The fluid’s high density and favorable thermodynamic properties allow compact, high speed turbomachinery with excellent cycle efficiency.

Key characteristics:

High energy density: small volumes deliver significant power.
Efficiency: thermal-to-electric efficiency of 45 to 55 percent for waste heat recovery.
Challenges: turbomachinery must withstand very high speeds and pressures, requiring advanced seals, bearings, and materials.