White Paper
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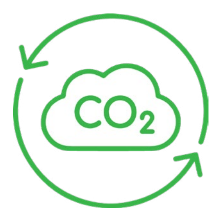
Control Valve Solutions for Carbon Capture, Utilization, and Storage

CCUS has been found to be an integral part in the ability to meet net zero goals



Climate change has gained the attention of global organizations and lawmakers, all coming to the same conclusion- greenhouse gases (GHG) and their effects must be addressed. To limit the effects of climate change and meet net zero goals, carbon capture, utilization, and storage (CCUS) is essential. Large point sources such as fossil fuel power plants and fuel processing plants emit a significant amount of greenhouse gas emissions every year, mostly carbon dioxide.

Despite worldwide efforts to reduce CO_2 and other GHG in the atmosphere, the annual surface temperature is still on the rise. Due to this, mitigation strategies are increasing even more quickly, and more technologies unavailable now will become mature enough for commercialization.

The act of separating CO_2 from other materials for use has been around for decades, and knowledge from past experiences has helped shape growing CCUS efforts. Fisher™ control valves have been used for over 50 years in amine-based acid gas removal applications for enhanced oil recovery (EOR). This experience has led to top industry expertise and first-in-class control valve solutions along the entire CCUS value chain.

CCUS Value Chain

Control valves are used throughout the CCUS value chain, from initial separation of CO_2 from other materials to utilization or sequestration in the final stage. At Emerson, we have extensive experience in providing the optimal solution for control valve requirements.

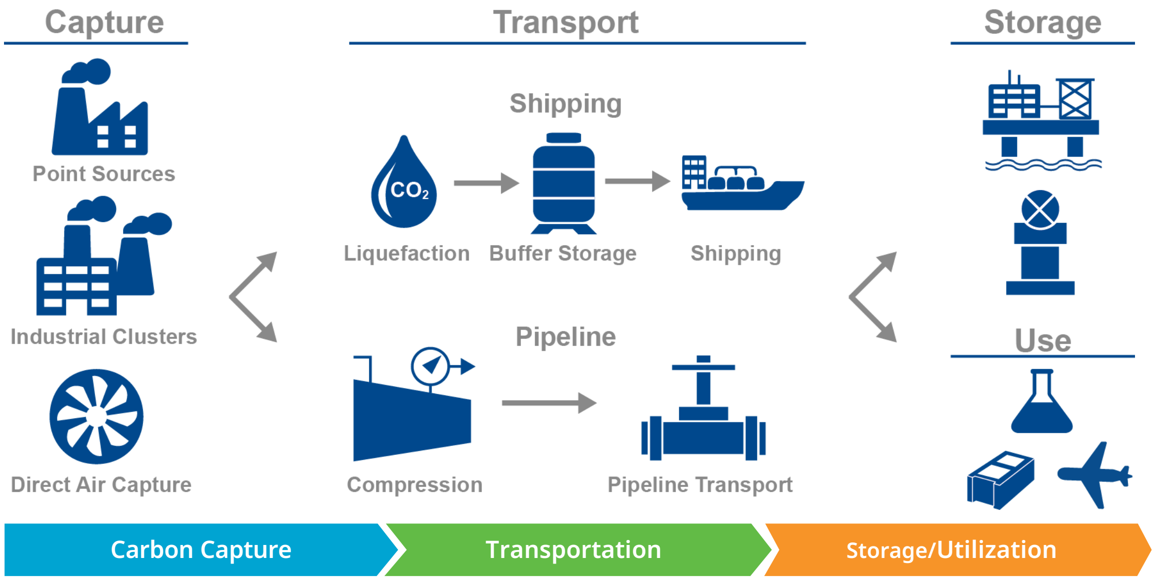


Figure 1. CCUS Value Chain Diagram

Carbon Capture Systems

Post-Combustion Capture

Post-combustion carbon capture (PCC) technology involves capturing CO_2 from flue gas after the combustion in air of a fuel source such as fuel oil, coal, natural gas, waste, or biomass. Due to the presence of impurities, the flue gas must first undergo several processes such as denitrification, desulphurization, and dust removal before capture. The method of CO_2 separation depends on conditions such as the fuel used, the composition of CO_2 within the gas to be treated, the partial pressure of CO_2, and the capture system chosen. Amine-based acid gas removal using absorption technology has been used in gas-treating plants for many decades, making chemical absorption based on traditional amine solvents the most mature CO_2 capture process. This technology is widely used in large industrial plants, fertilizer, natural gas processing, and soda ash. Around 80% of commercial energy comes from fossil fuel combustion; due to this, PCC is important in mitigating CO_2 emissions during the transition to renewable energy.

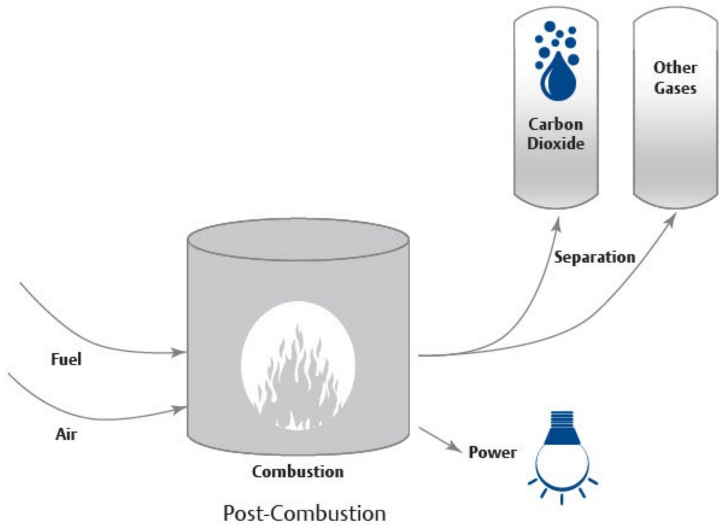


Figure 2. Post-Combustion Carbon Capture

Pre-Combustion Capture

Pre-combustion carbon capture involves the removal of CO_2 from a high concentration CO_2 fuel source such as coal or natural gas. Such as in post-combustion capture, impurities must be removed before processing. In this system, the fuel reacts with oxygen in a process called gasification, producing syngas. Next, the process goes through a water-gas shift reaction, where the syngas reacts with steam to promote the conversion of CO to CO_2 and excess hydrogen. The CO_2 is then separated from the hydrogen, cooled and compressed, then sent to be sequestered or used in industrial processes. Today's commercially available pre-combustion capture approaches utilize physical absorption within natural gas processing and coal gasification facilities.

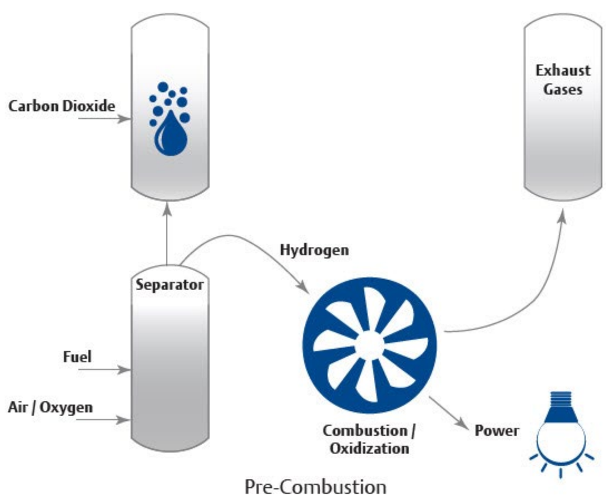


Figure 3. Pre-Combustion Carbon Capture

Direct Air Capture

Carbon Dioxide removal (CDR) technologies play an important role in reducing CO_2 emissions and achieving net-zero goals. Rather than capturing CO_2 from point sources or other industrial applications, CDR technologies focus on providing a solution for legacy emissions and balance emissions that are difficult to avoid. If used in tandem with CO_2 capture technologies, there is opportunity to create negative emissions. Currently, the only CDR technology used commercially is direct air capture (DAC). While adoption of this technology has been slow going, over the recent years installations of DAC facilities have increased, and the recognition of DAC to mitigate the effects of climate change is spreading more quickly than ever.

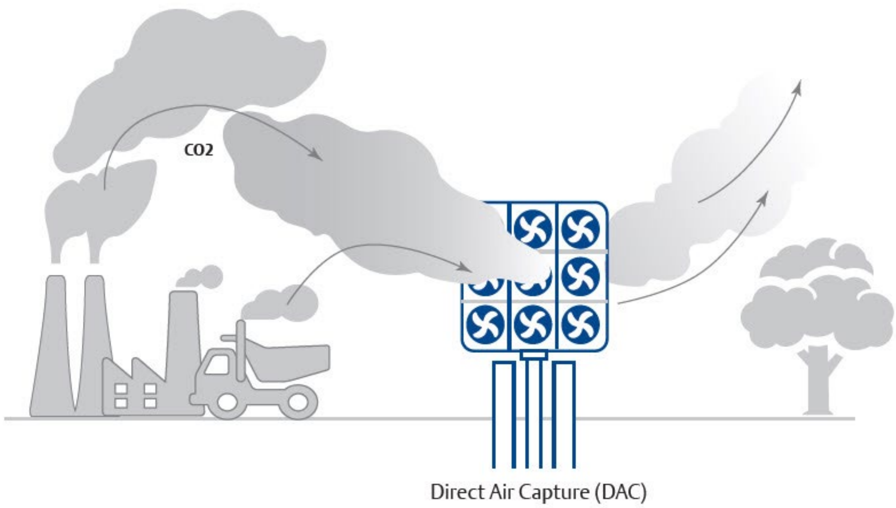


Figure 4. Direct Air Capture

Transportation

If CO_2 is not being used at the site of capture, it is transported to another site for use or sent for storage within geological formations. It can be transported by ship, rail, truck, or pipeline; however, pipeline travel has been found to be the most economical, safe, and efficient to operate. Preparing CO_2 for travel involves dehydration to remove as much free water as possible then sending the CO_2 through a series of multi-stage compressors to compress the stream to a pressure above the critical point of CO_2 into a supercritical fluid stage. This fluid holds a density that is very close to a liquid as well as a viscosity much closer to that of a vapor, creating a unique dynamic equilibrium that requires vigilance through the process.

Utilization and Sequestration

At the end of the transport stream lies a few options for CO_2; for direct utilization in industry, it can be transformed into various fuels, chemicals, or building materials for indirect use, and permanent sequestration into the ground. Utilization pathways include (but not limited to) urea manufacturing, enhanced oil recovery (EOR), metal fabrication, and food and beverage production. Most commercial applications today utilize CO_2 directly, though it is not seen as an alternative for large-scale emission reductions as of now. The future market potential is difficult to track, as barriers and early technology development stand in the way.

To truly make carbon capture successful, efficient storage for the CO_2 must be available. Most of the current captured CO_2 is sequestered into porous rock formations such depleted oil or gas reservoirs and saline aquifers. A feature of a CO_2 injection well is an impermeable seal (caprock) to prevent any seepage out of the subsurface, providing long-term and safe storage of CO_2 completely isolated from the atmosphere. The CO_2 sent for injection can either be used for permanent sequestration or EOR. These two avenues are revered as prime storage solutions for captured anthropogenic CO_2, with supercritical CO_2 as the chosen injection agent. When supercritical CO_2 is injected at depths of over 800 meters, the reservoir pressure keeps the CO_2 supercritical, making it less likely to migrate out of the reservoir.

Supercritical CO2 Properties

As stated before, supercritical CO_2 is the chosen agent for the transportation and sequestration of anthropogenic CO_2 emissions. To transform CO_2 into a supercritical fluid, it must go through a series of multi-stage compressors to be compressed above its critical point of approximately 31°C and 1073 psi. The enthalpy curve outlining the physical properties of CO_2 is shown below (Figure 5).

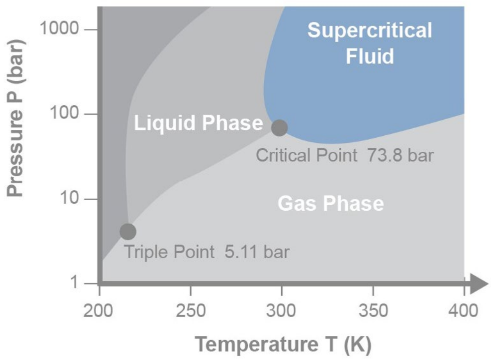


Figure 5. Enthalpy curve outlinin the physical properties of CO_2

As seen in the figure above, changes in temperature and/or pressure of the CO_2 can change its physical state as well as other thermodynamic properties, such as density. These changes can bring challenges such as cavitation, outgassing, high vibration and noise, and erosion.

To properly understand supercritical CO_2 and gain the correct sizing elements, control valve experts should be consulted first and foremost. Utilizing these technologies and best practices can help the world meet their total net zero targets while implementing sustainable practices that will last indefinitely.

Emerson Control Valve Solutions for CCUS Value Chain

Emerson has supplied control valves for various segments within the carbon capture value chain for many years. The following table shows the different processes and recommended control valve solutions for each application within CCUS.

Please note that more than one solution can apply to a process- some solutions may require a combination of standard and severe service options depending on the application. Consulting Emerson control valve experts will guarantee well-chosen and robust valves for your application.

Unit	Process	Application	Globe Valves		Engineered Products	Rotary Valves
			Fisher™ easy e™/ Fisher GX 	Fisher HP/EH High-pressure 	Fisher CAV4 / Fisher DST 	Fisher Pipeline series 
Carbon Capture	Absorption	Learn amine feed control	Noise and outgassing			
		Rich solution absorber level control	Noise, Superficial Fluid			
	Pump	Learn amine pump recirculation control	Noise and outgassing			
	Separation	Separator pressure control	Noise	Noise		
		Contractor level control	Noise and outgassing	Noise and outgassing		
Processing	Compression	Compressor anti-surge	Noise, (drop icon)			
Transportation	Transportation & Compression stations	Flow control				Noise, (drop icon)
Sequestration	CO_2 Injection	Pressure control for injection		Noise, Superficial Fluid, (drop icon)	Noise, Superficial Fluid, (drop icon)	

Legend:

Proposed Solution (blue cell) — Noise — Noise and outgassing — Superficial Fluid

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