Cryogenic Carbon Capture™ FAQs

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What is Cryogenic Carbon Capture™

Cryogenic Carbon Capture (CCC) is a post-combustion process that freezes carbon dioxide out of waste streams in the form of dry ice.

How does it work?

Cryogenic Carbon Capture (CCC) works by cooling down a waste stream containing carbon dioxide. When the waste stream is cold enough, the carbon dioxide freezes into dry ice. The dry ice is then separated from the non-condensable gases (usually nitrogen). The cold nitrogen and dry ice are utilized in recuperative heat exchangers to assist in cooling down the incoming waste stream. During the recuperative step, the dry ice melts, forming liquid carbon dioxide. The liquid carbon dioxide is pumped up to pipeline pressures for transport.

Is carbon dioxide harmful?

Carbon dioxide (abbreviated CO_2) is a greenhouse gas emitted by power plants, automobiles, and anything else that burns fossil fuels. Small amounts of carbon dioxide are present naturally in the air. But anthropogenic (human-made) sources of carbon dioxide have been causing carbon dioxide levels to rise. Of all anthropogenic sources of carbon dioxide, 87% are from the burning of fossil fuels. Of these, 41% are from power and heat generation, such as in coal or natural gas power plants. Carbon dioxide absorbs infrared radiation (heat) and radiates it back to Earth. The trace amounts of carbon dioxide present in Earth's atmosphere warm the surface, making life possible. Without naturally occurring carbon dioxide, Earth would be too cold to sustain life. Since the start of the industrial revolution, anthropogenic carbon dioxide emissions have amplified the natural greenhouse effect, causing the average surface temperature of Earth to warm by about 0.85°C (1.53°F). The warming is projected to continue throughout the century. This warming results in climate change, rising ocean levels, and other detrimental effects.

What is done with all the carbon dioxide that is captured?

There are some potential uses for carbon dioxide, such as enhanced oil recovery, but for the most part it is considered waste and thus would be sequestered in deep underground aquifers and other formations. However, certain industrial processes that require carbon dioxide as a feedstock and are in close proximity to a large source of carbon dioxide, such as a cement plant or fossil fuel power plant, may benefit economically from carbon capture.

In Cryogenic Carbon Capture, how cold do you have to get the carbon for it to freeze?

The exact temperature depends on how much carbon dioxide you want to remove. To remove 99% of the carbon from a coal-fired combustion process, the entire waste stream must be cooled to -132 °C (-205.6 °F). After the dry ice is separated from the non-condensable gases, both streams are re-warmed in recuperative heat exchangers and delivered at ambient temperature.

That is a very low temperature to cool the entire exhaust stream from a power plant. I would expect that the refrigeration system would require a tremendous amount of energy.

At first glance this does appear to be the case. However, by closely matching temperature profiles in recuperative heat exchangers, the refrigeration requirements are reduced about 20-fold. As a result, the energy penalty associated with CCC is very low—about half that of competing carbon capture processes.

How do recuperative heat exchangers reduce the energy requirement of CCC?

The majority of the cooling in CCC is accomplished using the cold non-condensable gas and dry ice products. The products cool the incoming waste stream in a recuperative plate-and-frame heat exchanger. The products are themselves warmed and delivered at ambient temperature. Therefore, only a small amount of make-up refrigeration is required. From a total energy balance perspective, the make-up refrigeration needs only to reject the heat of vaporization of carbon dioxide as it is converted from the gas phase to the liquid phase. We are doing that very efficiently using heat integration, without any expensive CO_2 gas compression.

Does CCC capture any other pollutants besides carbon dioxide?

Yes. Many pollutants that are present in coal exhaust, such as NOx, SOX and mercury, condense at the cryogenic temperatures achieved in CCC and are also captured. For greenfield installations, this capability of CCC can offset the cost of traditional pollutant capture systems.

Will CCC increase the cost of electricity?

Yes, but not as much as other alternatives. According to the National Energy Technology Laboratory (NETL), a post-combustion amine system that captures 90% of the carbon dioxide from a coal-fired power plant would raise the cost of electricity by 4.8 ¢/kWh. An equivalent Cryogenic Carbon Capture system would raise the cost by only 2.6 ¢/kWh.

Is there any potential for energy storage with CCC?

Yes. Energy Storing Cryogenic Carbon Capture™ (CCC-ES) is a special implementation of CCC for power generation. It enables efficient grid-scale energy storage and carbon capture with little to no effect on peak plant capacity.

How does Energy Storing Cryogenic Carbon Capture (CCC-ES) work?

In all implementations of CCC, carbon dioxide is condensed, and subsequently captured, through heat exchange with a cold refrigerant stream. CCC, like all carbon capture processes, requires electricity to operate, and most of the electricity used by CCC and CCC-ES is directed towards producing the cold refrigerant. When excess power is available on the grid, CCC-ES can generate excess refrigerant and store it in cryogenic tanks. Later, when the demand for power is high, CCC-ES can use the stored refrigerant to continue operating. Thus, CCC-ES can adjust its electricity demand in real time for grid-scale load balancing.

But where is the "energy" stored in CCC-ES?

The energy is stored in the form of cryogenic refrigerant. Storing this refrigerant means that during peak demand, CCC-ES can ramp down its own electricity usage to near zero, allowing additional power to be delivered to the grid.

What is the round-trip energy storage efficiency of CCC-ES?

It is estimated to be near 99.5%. In traditional energy storage methods, electrical power is converted to another form of energy, such as potential energy, during storage and converted back to electrical power during peak demand. This conversion introduces inefficiencies. In CCC-ES, however, the energy is stored in the same form the entire time. There is no conversion from one form of energy to another and the only losses are due to heat transfer through the cryogenic storage tank wall.

What benefits are there for CCC-ES?

Other carbon capture technologies consume a fraction of the power plant's electrical output as what is known as a *parasitic load*. This reduces the total output of the plant. CCC-ES also has a parasitic load, but it can be adjusted up or down based on current power demand or availability of intermittent sources. Thus, the plant can retain its full nameplate capacity during peak demand while still capturing carbon dioxide.

Does it make sense to implement CCC-ES solely for its energy storing capability?

No. The primary objective of CCC-ES is carbon capture. Energy storage is a secondary objective that can perform grid load balancing and which allows the plant to retain its full nameplate capacity during peak demand.

If Cryogenic Carbon Capture is so much better, why doesn't everyone use it?

SES is still developing and improving the technology. To date, several small pilot units have been demonstrated successfully in the lab and on site at multiple locations. SES plans to design and contract the construction of a large pilot unit to be installed semi-permanently at a host site, with full-scale commercialization within five years.

What results have you gotten with your small pilot units?

Each unit regularly removes 95% of the carbon dioxide from the entering waste stream, but this number often exceeds 99%. Most of our run time takes place in our lab with simulated flue gas, but our small pilot units have also been tested with real flue gas at Pacificorps' Dave Johnston plant (coal), Holcim's Devil's Slide plant (cement processing), and at Brigham Young University's heating plant (coal and natural gas) and experimental reactor (coal, natural gas, and biomass). The multi-pollutant removal capabilities have also been demonstrated, achieving as-predicted levels of SOx and NOx in the output stream and no detectable mercury.

What is your energy usage on the small pilot units? Is it close to your predicted value?

We don't report those values because the small pilot units were not designed with efficiency in mind. They were intended as demonstration units to prove out the technology. The large pilot unit, however, will benefit from economies of scale and is projected to use less energy than existing carbon capture technologies.