

Research and Development Toward Saving Energy for Direct Air Capture With Available Cold Energy

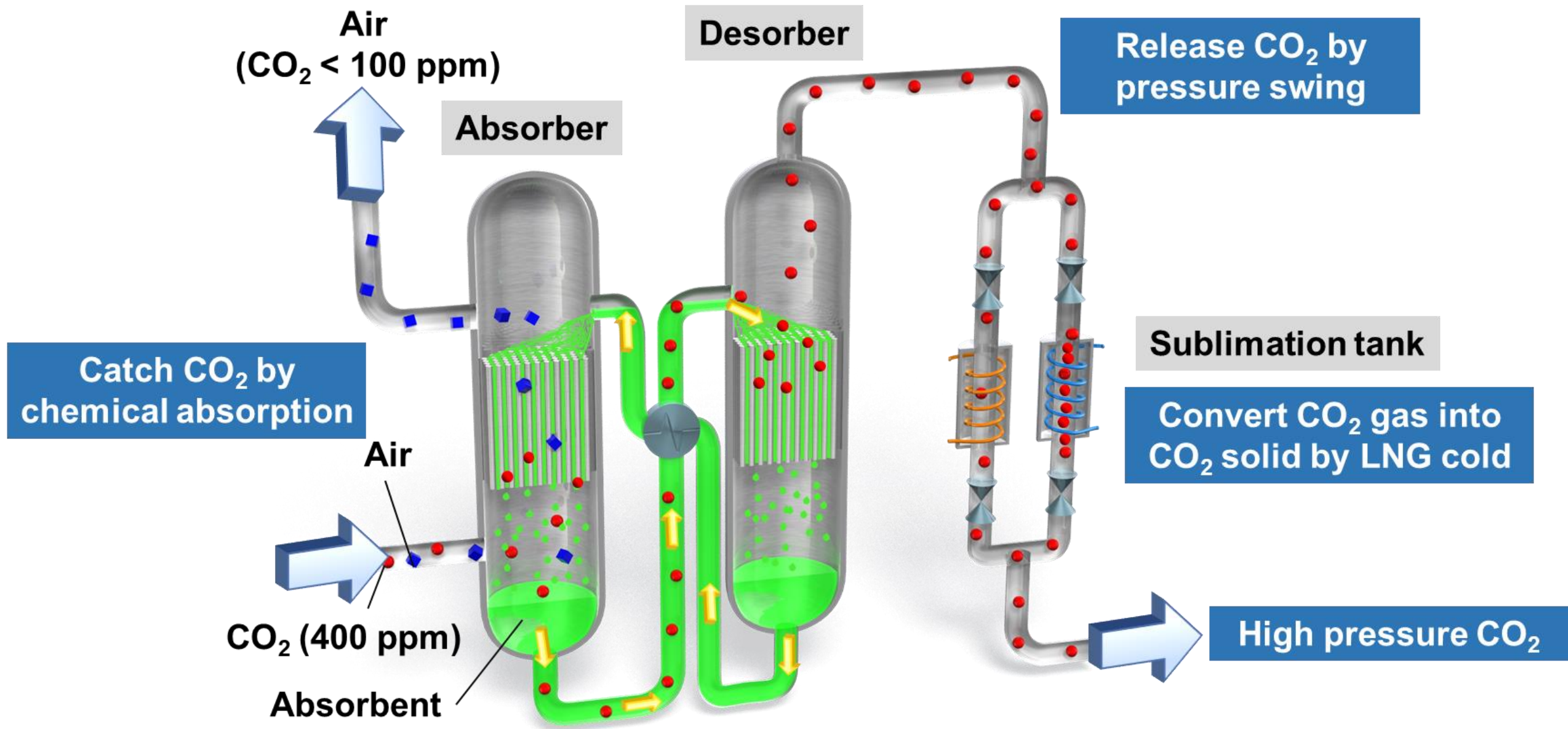
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Implementing organizations : Nagoya University, Toho Gas Co., Ltd., Tokyo University of Science

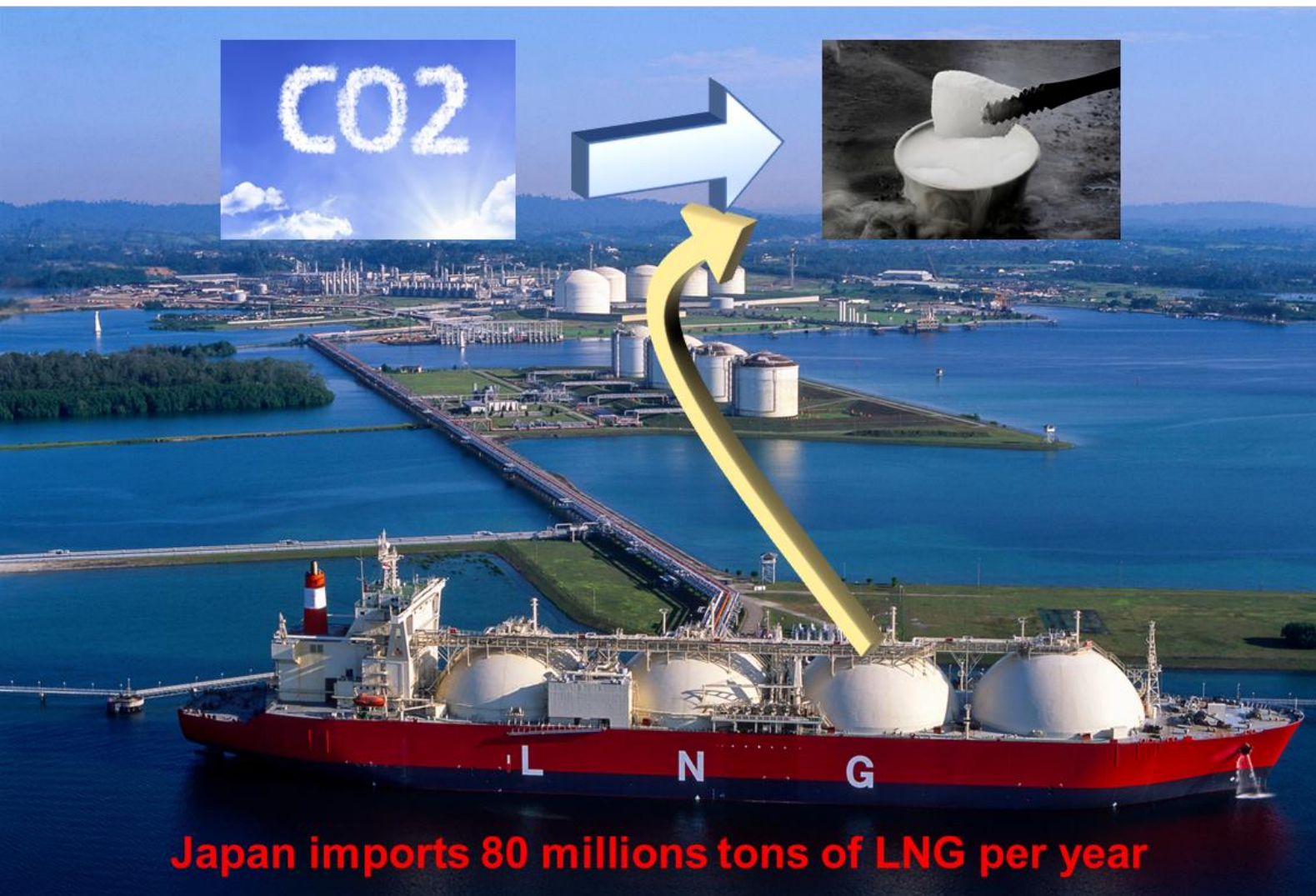
Cryo-DAC - process -

- A pressure swing amine process driven by the cryogenic pumping with LNG cold



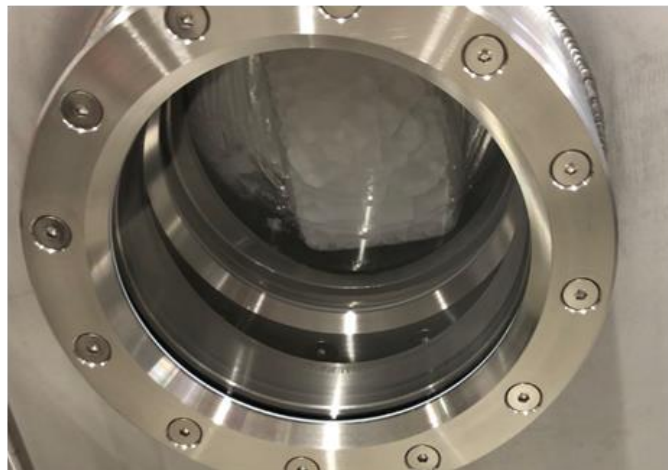
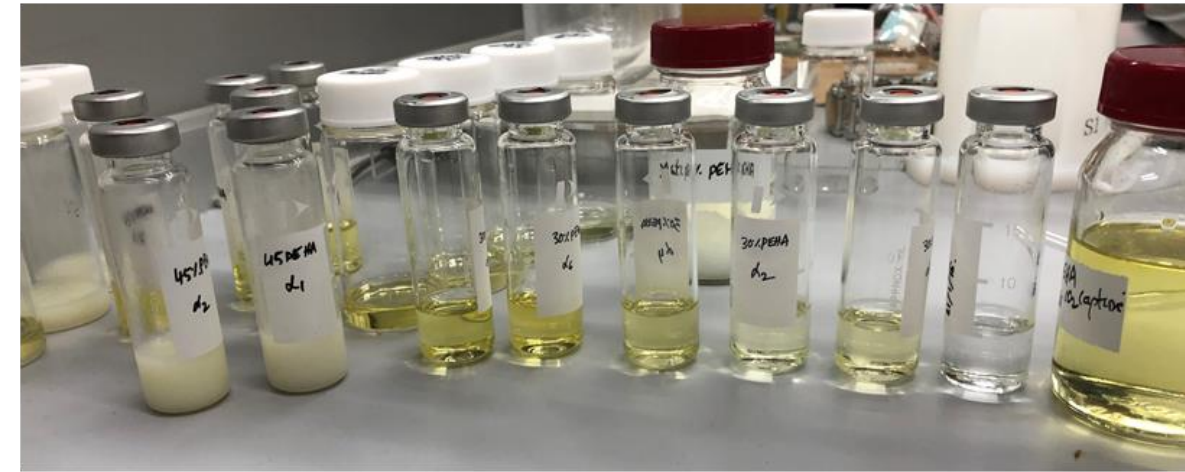
Cryo-DAC - our team -

- Use LNG cold for DAC



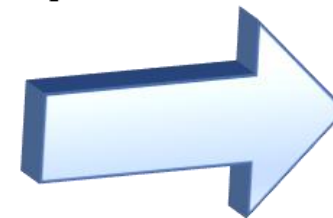
Cryo-DAC - advantages -

- Minimized thermal energy input
- Water in air can be accepted by amine
- High pressure and high purity CO₂ is output



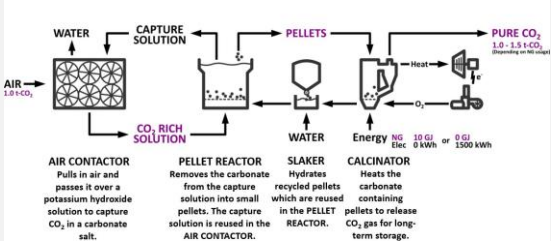
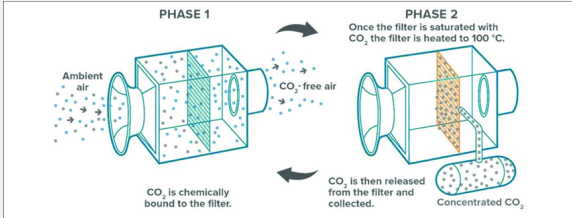
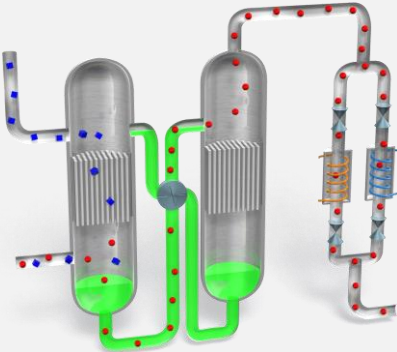
No further
compression and
purification

Cryo-DAC



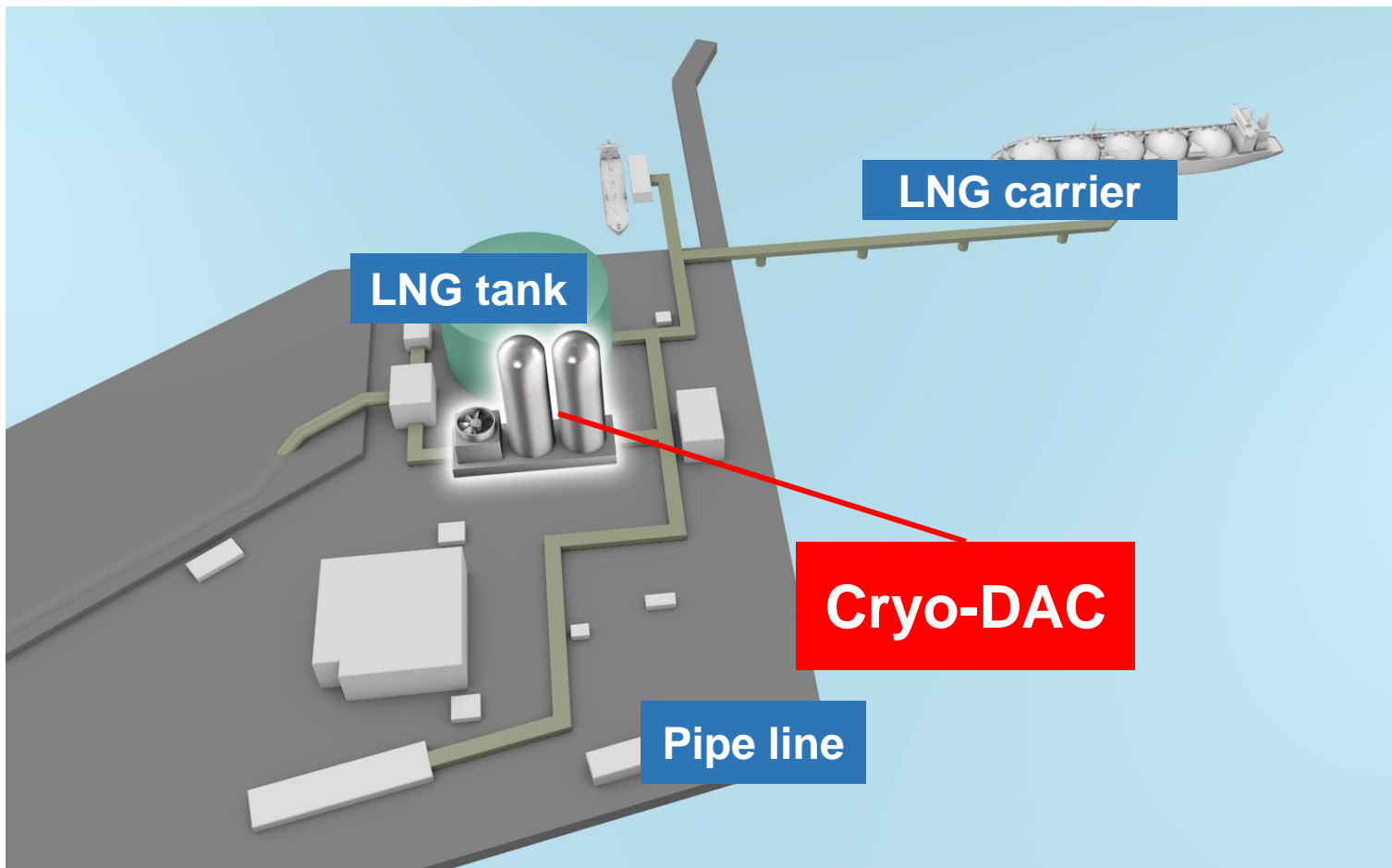
Storage and
Utilization

Other DACs vs Cryo-DAC

Developer	Carbon Engineering	Climeworks	Cryo-DAC
	 <p>The diagram illustrates the Carbon Engineering process. It starts with an AIR CONTACTOR where air (1.0 t CO₂) is pulled in and passed over a potassium hydroxide solution to capture CO₂ in a carbonate salt. This leads to a PELLET REACTOR where the carbonate is removed from the capture solution into small pellets. The capture solution is reused in the AIR CONTACTOR. The pellets go to a SLAKER where they are hydrated with water. The hydrated pellets are then moved to a CALCINATOR where they are heated to release CO₂ gas for long-term storage. The carbonate-containing pellets are recycled back to the PELLET REACTOR. Energy requirements are noted as 10 GJ Elec or 8 GJ kWh for the calcinator, and 1.0 - 1.3 t CO₂ (depending on the plant).</p>	 <p>The diagram shows the T-swing process in two phases. PHASE 1: Ambient air is passed through a filter where CO₂ is chemically bound. PHASE 2: Once the filter is saturated with CO₂, it is heated to 100 °C, releasing concentrated CO₂ gas. The filter is then cooled and ready for the next cycle.</p>	 <p>A 3D rendering of the Cryo-DAC system, showing two vertical cylindrical columns connected by a network of pipes and valves. The system is designed for liquid absorption and pressure swing regeneration.</p>
Principle	Aqueous alkali solution, T-swing	Solid absorbent, T-swing	Liquid absorbent, P-swing
Th Energy requirements, per captured CO ₂ (relative)	100✘	41✘	40
Sorbents regeneration temperature, °C	900✘	80-120✘	25

✘McQueen, N.; Gomes, K. V.; McCormick, C.; Blumanthal, K.; Pisciotta, M.; Wilcox, J. A Review of Direct Air Capture (DAC): Scaling up Commercial Technologies and Innovating for the Future. *Prog. Energy* **2021**, 3 (3), 032001.

Cryo-DAC - perspective -



LNG imports share %(2020)

BP Statistical Review
of World Energy 2021 | 70th edition

Japan	21
China	19
South Korea	11
India	7
Taiwan	5
Total Europe	24

- Cryo-DAC can be implemented to a city gas plant and capture CO_2 from the air and output high pressure or liquefied CO_2 .
- Captured CO_2 can be geologically stored or converted to carbon neutral methane, etc.

Cryo-DAC - study is going on -

- We found a good amine that absorbs CO₂ in air (~40 Pa) and release more than half of the absorbed CO₂ at 10 Pa that is the pressure of stripper as well as the dry ice sublimation pressure at -150°C.
- Process simulation based on the equilibrium properties of the amine indicates that the Cryo-DAC can be operated with much lower thermal energy input than the benchmark technologies.
- We are going to design and install a bench scale (~1 t-CO₂/y) and a pilot scale plant toward realization.



