



Pumps and Compressors for Carbon Capture, Utilization and Storage

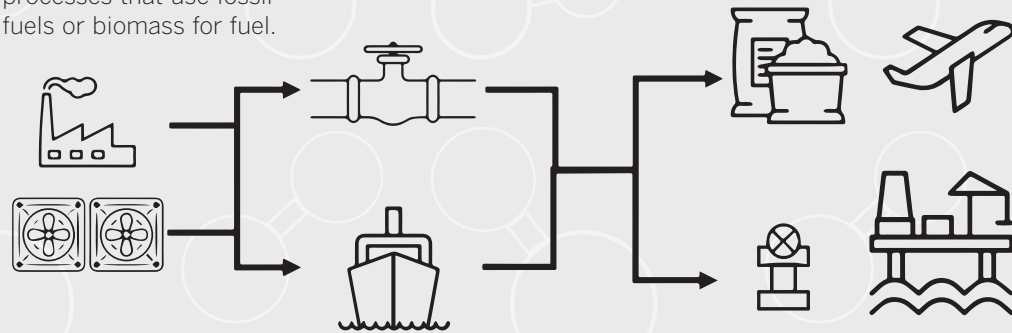


What is Carbon Capture, Utilization, and Storage (CCUS)?

Carbon Capture, Utilization, and Storage is a set of processes used to “capture” carbon dioxide from large-scale industrial and power generation emissions sources. Once CO₂ is captured, it can be transported for use in industrial processes or for safe and permanent sequestration underground.

Capture

Capturing CO₂ from processes that use fossil fuels or biomass for fuel.



Transport

Moving compressed CO₂, typically via pipeline or ship.

Utilization

CO₂ has been used for urea manufacturing and enhanced oil recovery (EOR). New utilization pathways include producing fuels, chemicals and building materials.

Storage

Safe and permanent sequestration of CO₂ underground in saline aquifers or abandoned oil & gas reservoirs. Carbon storage can be done onshore or offshore.

Why is CCUS Important?

According to the International Energy Agency (IEA), CCUS could account for 15% of all CO₂ emissions reductions by 2050 with 4.0 GT of CO₂ captured per year.¹ There are several key advantages to CCUS as a decarbonization technology:

- CCUS technology is ready today and can be scaled to capture CO₂ emissions from any size emissions source, including power generation and industrial hard-to-abate emissions.
- CCUS serves processes that use fossil fuels, so it can be deployed in today's energy mix without requiring new energy sources or production methods to be deployed.
- CCUS is an enabler to blue hydrogen, synthetic fuels production, direct air capture (DAC), and can be installed with biofuels production to produce negative-emissions fuels.

Multiple Technology Options

There are four main categories of carbon capture technology:

1. **Pre-combustion:** removing CO₂ from fossil fuels before combustion to produce syngas
2. **Post-combustion:** separating CO₂ from flue gas after fossil fuel or biomass combustion
3. **Oxy-fuel combustion:** burning fuel with pure oxygen (rather than air), resulting in a nearly pure CO₂ stream
4. **Direct Air Capture:** removing CO₂ directly from the atmosphere

Within each capture technology, there are various CO₂ separation techniques. These include absorption, adsorption, membranes, and cryogenics.

This brochure covers several processes within the carbon capture value-chain where Sundyne's product portfolio offers a superior solution.

¹ IEA (2020), CCUS in Clean Energy Transitions, IEA, Paris <https://www.iea.org/reports/ccus-in-clean-energy-transitions>. License: CC BY 4.0

Pre-Combustion Capture

Pre-combustion capture processes remove CO₂ from fossil fuels before they are burned. Once the CO₂ is removed, the resulting syngas is H₂-rich and can be used as a clean fuel in industrial or power generation processes. The process involves gasification, syngas processing, CO₂ capture and hydrogen production.

1 Gasification:

The first step in pre-combustion carbon capture is to convert a fossil fuel (such as coal or natural gas) or a biomass fuel into a synthetic gas (syngas). This process occurs in a gasifier, which reacts the fuel with oxygen and steam in order to break it down into primarily carbon monoxide (CO) and hydrogen (H₂). Gasification varies based on the feedstock.

2 Syngas Processing:

The syngas mixture containing CO and H₂ is then sent through a catalytic shift reactor, where a water-gas shift reaction occurs. The CO reacts with steam (H₂O) to form additional H₂ and CO₂. The resulting syngas mixture has higher concentrations of CO₂ (making it easier to separate) and higher concentrations of H₂ (for subsequent use as a clean fuel).

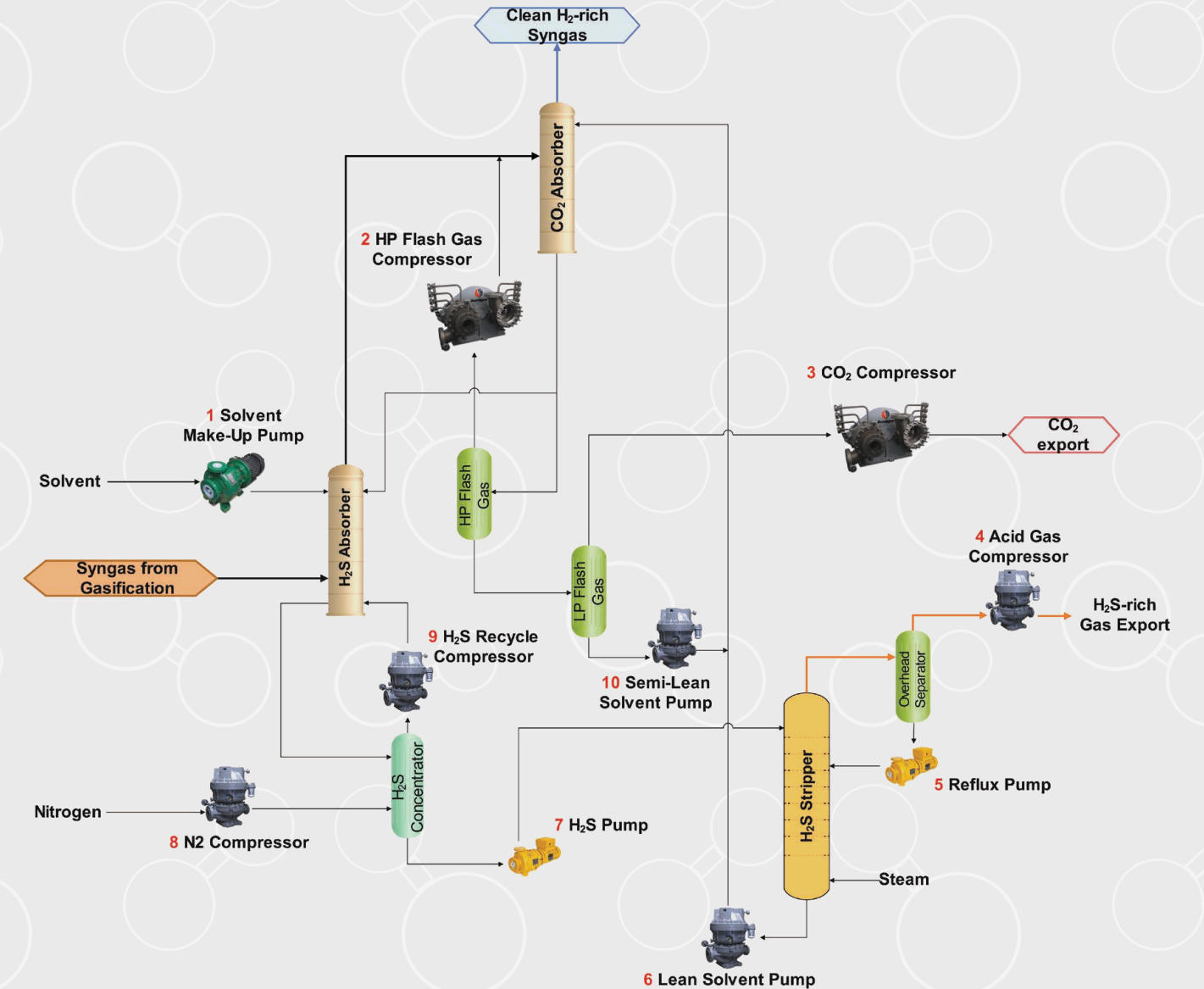
3 H₂S Removal and CO₂ Capture:

Any remaining H₂S must be removed from the syngas, since H₂S is a corrosive gas that can poison the catalysts used in carbon capture, damage equipment downstream, and can result in the emission of SO₂ which is a major air pollutant. The syngas is sent through an absorption tower, where an amine solution absorbs the H₂S and any other sulfur compounds. The H₂S-rich amine solution is then pumped to a regeneration tower, where the H₂S is released, and the lean-amine can be reused.

Next, the CO₂ is separated from the syngas. In pre-combustion capture, various technologies can be used to separate the CO₂, including physical solvents, chemical solvents, and membrane separation. In the diagram shown here, a chemical solvent is used to separate the CO₂ in the CO₂ absorber tower. Since the CO₂ is being removed from the pre-treated syngas mixture, the CO₂ concentration is higher than it would be for post-combustion capture solutions. For this reason, the overall energy-usage in the pre-combustion process is lower than in post-combustion carbon capture..

4 Hydrogen Production:

Once the CO₂ has been removed, a hydrogen-rich syngas remains. This "clean hydrogen" can be used as a fuel in various applications, including industrial heat, electricity generation, or for transportation.



Location	Service	Sundyne Equipment	Medium
1	Solvent Make-Up Pump	Ansimag, LMV, HMD, Marelli	Amine
2	HP Flash Gas Compressor	LF-2000	CO ₂ , H ₂ , N ₂ , H ₂ O
3	CO ₂ Compressor	LF-2000	Wet / Dry CO ₂
4	Acid Gas Compressor	LF-2000, LMC/BMC	H ₂ S, CO ₂
5	Reflux Pump	HMD, LMV	Amine + CO ₂
6	Lean Solvent Pump	LMV, HMD, Ansimag, Marelli	Amine
7	H ₂ S Pump	HMD, LMV	H ₂ S
8	N ₂ Compressor	LMC/BMC	N ₂
9	H ₂ S Recycle Compressor	LMC/BMC	H ₂ S
10	Semi-Lean Solvent Pump	LMV, HMD, Ansimag, Marelli	Amine, CO ₂ , H ₂ S

Post-Combustion Capture with Chemical Absorption

Amine-based absorbents are the most common and effective solvents for chemical absorption. Amines bond with CO₂ to absorb and remove CO₂ molecules from gas streams. There are many technology providers who offer chemical absorption process licenses and propriety amine solvent formulas. An amine-based scrubbing process unit can be installed as a retrofit onto any industrial process with a flue gas stream containing 3% to 20% CO₂ concentration. The CO₂ removal from flue gas by amine wash process works as follows:

1 Pre-Treatment:

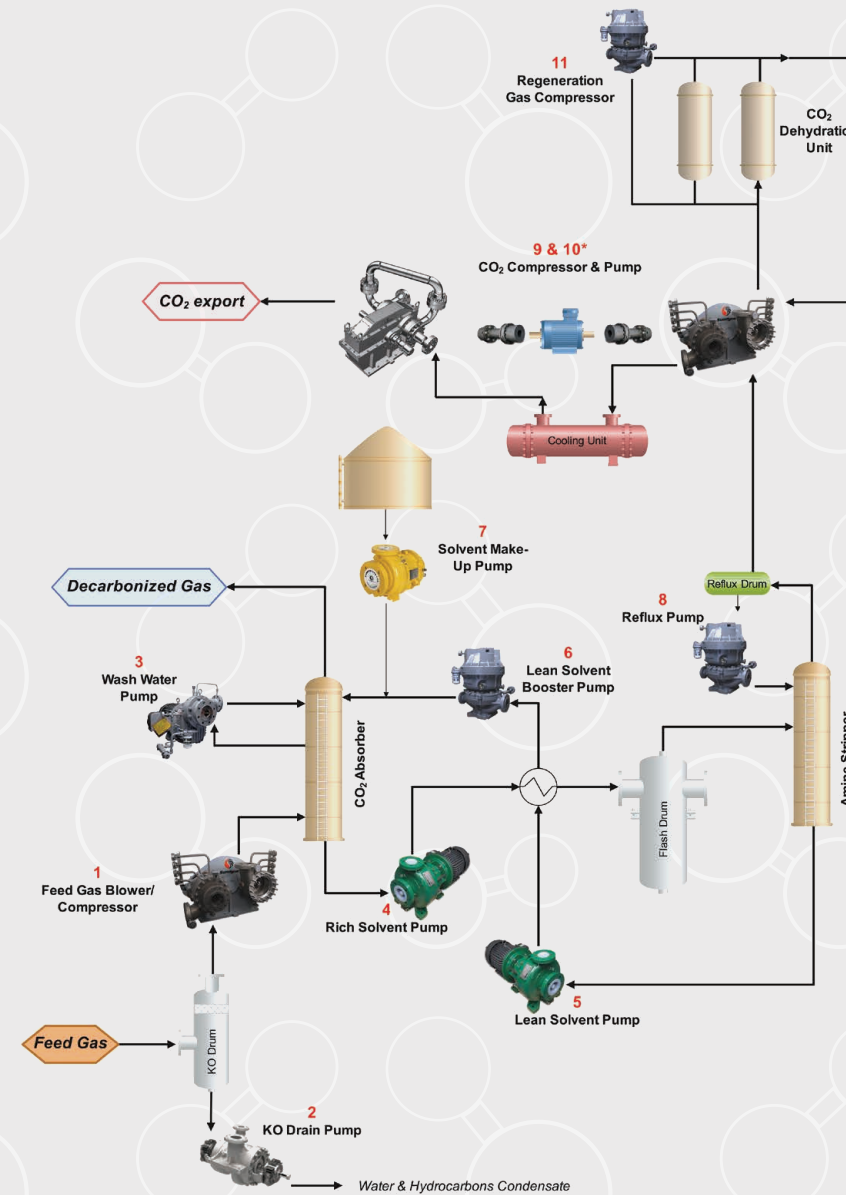
A Gas Blower or Gas Compressor moves the flue gas into a vapor-liquid separator (called a KO, or knockout drum), which removes water and liquid hydrocarbons from the gas stream. The flue gas stream is also cooled prior to being fed into the absorption tower.

2 Absorption:

The untreated "sour" gas moves into the CO₂ absorber. Here, circulation pumps inject aqueous lean amine solutions that bind onto CO₂. The treated gas leaving the absorption column is CO₂ free and can be released into atmosphere.

3 Desorption and Regeneration:

The "rich amine" (now containing the CO₂) settles at the bottom of the absorber, where it is fed to the regenerator using sealless pumps. The pumps used in this process must be capable of supporting extremely high temperatures. Steam, generated in the reboiler, heats the amine and removes CO₂ in the amine stripper. The "lean amine" from the regenerator is cooled in an exchanger, where it is returned to the absorber to be re-used. At the top of the regenerator, the released CO₂ is saturated with water. The gas is routed through a reflux drum to condense the water vapor and remove any residual amine, which is then pumped back to the regenerator. The removed CO₂ is concentrated and can be sent to a pipeline for sequestration or other utilization end-markets.

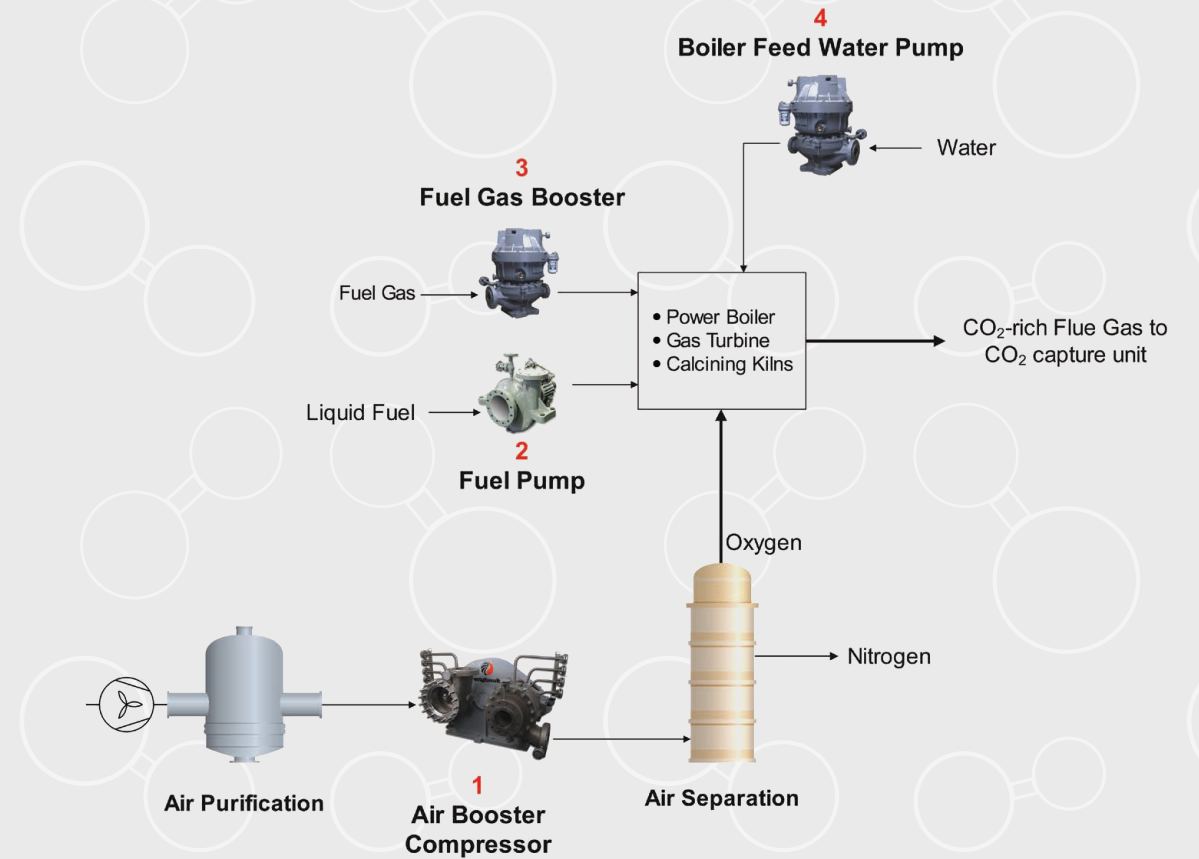
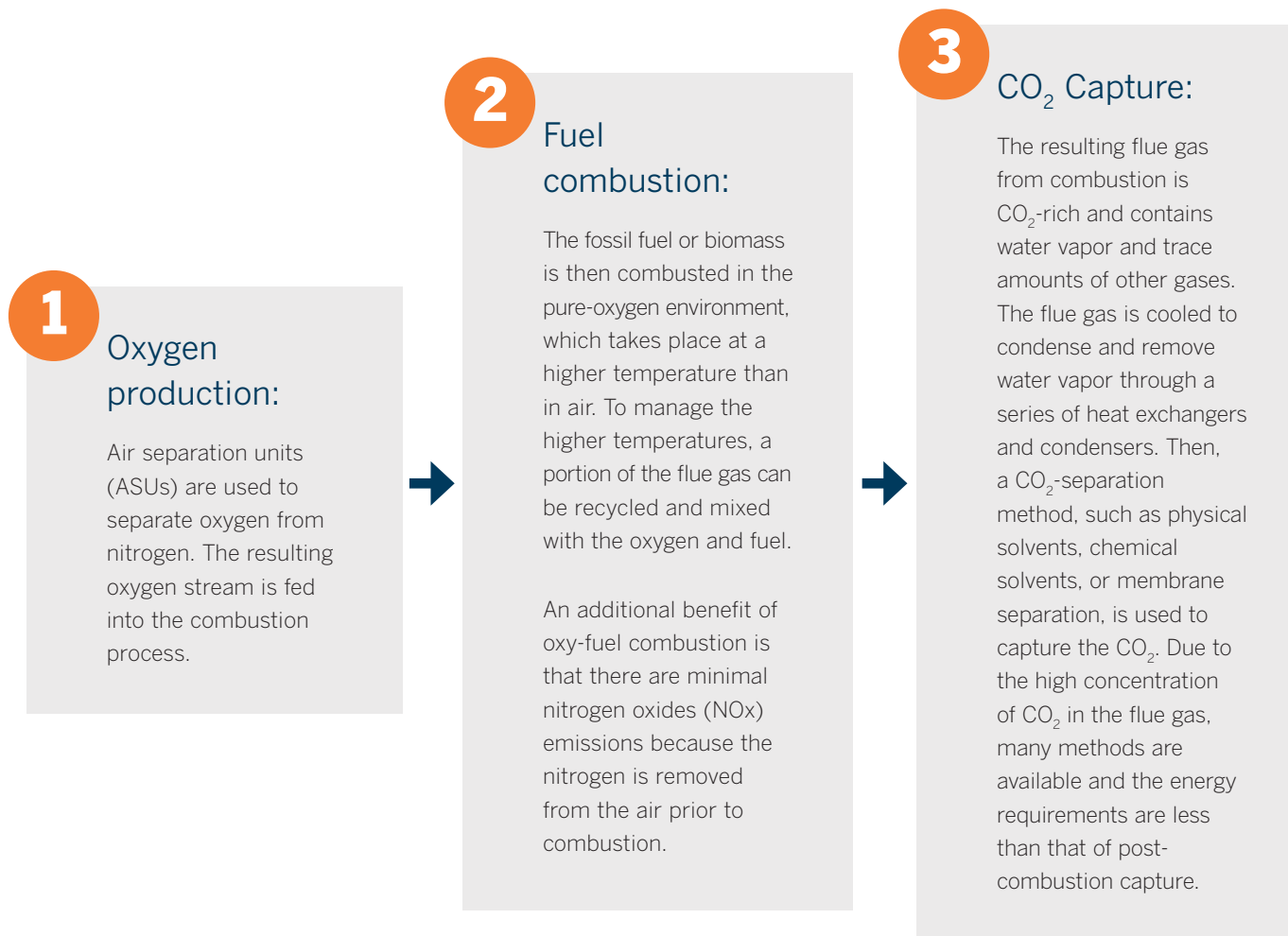


Location	Service	Sundyne Equipment	Medium
1	Feed Gas Compressor	LF-2000	Flue Gas
2	KO Drain Pump	Marelli, LMV	Water, HC Condensate
3	Wash Water Pump	Marelli, LMV	Water, Amine
4	Rich Solvent Pump	LMV, HMD, Ansimag, Marelli	Amine + CO ₂
5	Lean Solvent Pump	LMV, HMD, Ansimag, Marelli	Amine
6	Lean Solvent Booster Pump	LMV, HMD, Ansimag, Marelli	Amine
7	Solvent Make-Up Pump	LMV, HMD, Marelli	Amine
8	Reflux Pump	Marelli, LMV	Amine + CO ₂
9	CO ₂ Compressor*	LF-2000	Wet CO ₂ , Dry CO ₂ , sCO ₂
10	CO ₂ Pump*	LMV, Marelli	Liquid CO ₂
11	Regeneration Gas Compressor	LMC/BMC, LF-2000	CO ₂ , Water

* Sundyne offers the unique ability to integrate multiple services within a single machine, including an integrated CO₂ pump and CO₂ compressor mounted on one skid with one motor. Whenever CO₂ is compressed to a supercritical state or whenever CO₂ is liquefied then pumped, a dual-service machine guarantees the best integration of process & control management within a compact and modularized arrangement.

Oxy-Fuel Combustion

Oxy-fuel combustion involves burning fossil fuels or biomass in an oxygen-rich environment instead of in air. Burning fossil fuels in air (which is roughly 78% nitrogen, 21% oxygen, and 1% argon) results in a flue gas stream with diluted CO₂ concentration, requiring more energy-intensive post-combustion carbon capture processes to be deployed. In oxy-fuel combustion, the flue gas has a high CO₂ concentration, which makes the subsequent carbon capture, transport and storage much more efficient. The process involves oxygen production, fuel combustion, and CO₂ capture.



Location	Service	Sundyne Equipment	Medium
1	Air Booster Compressor	LF-2000	Air
2	Fuel Pump	Marelli	Liquid Fuel
3	Fuel Gas Booster	LMC/BMC, LF-2000	Natural Gas
4	Boiler Feed Water Pump	LMV, HMP, Sunflo	Water

Other Services

In addition to the carbon capture process, Sundyne equipment supports utilities and balance-of-plant services for CCUS projects. Here are some common services that Sundyne equipment can serve:

Other Services	Equipment Type	Medium
Boiler Feed Water Feed Pumps	Marelli, LMV, HMP, Sunflo pump	Water
Condensate Pump	Marelli, LMV, HMP, Sunflo pump	Water
Closed Cooling Water Pumps	Marelli pump	Water
Corrosion Inhibitor Pumps	HMD, Ansimag pump	Alkaline compounds Amine, Hydrazine
Demi Water Feed Pumps	Marelli, LMV, HMP, Sunflo pump	Water
Demi Water Circulation Pumps	Marelli, LMV, HMP, Sunflo pump	Water
Refrigerant Gas Compressors	Sundyne LMC/BMC or LF-2000	HCFC, CFC, HC, CO ₂ , Ammonia
Quench / Condenser Pump	Ansimag, HMD pump	Process Water

Direct Air Capture

Direct Air Capture (DAC) involves removing carbon dioxide directly from the atmosphere.

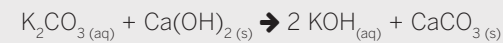
For this reason, DAC is viewed as a carbon removal technology, rather than a carbon abatement technology like the point-source carbon capture methods. There are two main types of DAC based on the CO₂ removal method: (1) liquid sorbents and (2) solid sorbents.

Liquid Systems

In liquid systems, a chemical solution (such as KOH, potassium hydroxide) absorbs CO₂ from the air and then forms a carbonate (K₂CO₃) or bicarbonate.



The potassium carbonate is reacted with calcium hydroxide pellets (Ca(OH)₂) in a pellet reactor to regenerate the KOH absorbent and create calcium carbonate (CaCO₃).



Then, the calcium carbonate is heated in a calciner to release the CO₂ and create calcium oxide (CaO).



The calcium oxide is reacted with steam in a slaker to produce calcium hydroxide pellets, which are sent back to the pellet reactor. This method is energy-intensive due to the need to regenerate the absorbent (similar to post-combustion carbon capture) however, it is highly effective in capturing CO₂ at low concentrations and can be operated continuously.

Solid Systems

In solid-sorbent systems, a solid-based adsorbent or metal-organic framework binds onto the CO₂ from the ambient air. The solid sorbent is then regenerated, typically using a temperature swing adsorption (TSA) process, to release the CO₂ and restart the process. For this reason, there are typically multiple sorbent beds installed so that one can be operating while another is being regenerated. This method has lower energy costs than liquid systems.

Process Steps

For both processes, the typical steps are as follows:

1. Ambient air contacting:

A set of fans or blowers brings the ambient air into contact with the sorbent system (either solid or liquid). These systems are often designed like industrial cooling towers to handle large volumes of airflow.

2. Carbon capture:

For liquid systems, CO₂ reacts with the liquid sorbent, forming a carbonate or bicarbonate which is processed in the regeneration step. For solid systems, CO₂ is adsorbed by the solid material through either chemical or physical bonds.

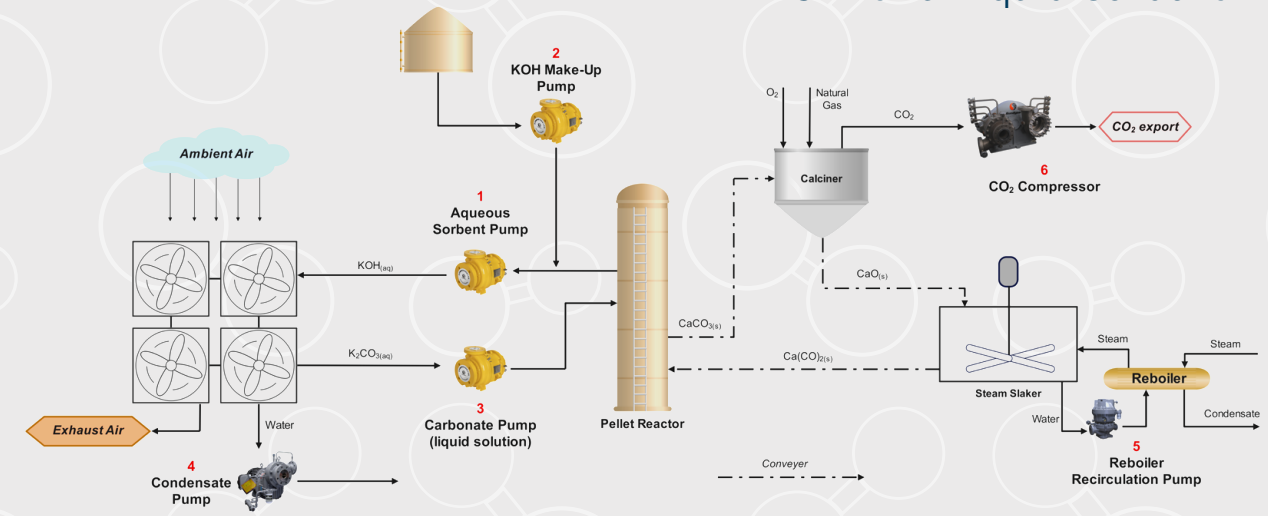
3. Sorbent regeneration:

Once the CO₂ is captured, it needs to be released and then the sorbent can be regenerated for reuse. In liquid systems, the carbonate is heated or reacted to release the pure CO₂ and recycle the liquid solution (such as KOH). In solid systems, the adsorbent is regenerated by applying either temperature or pressure swings.

4. CO₂ compression and transport:

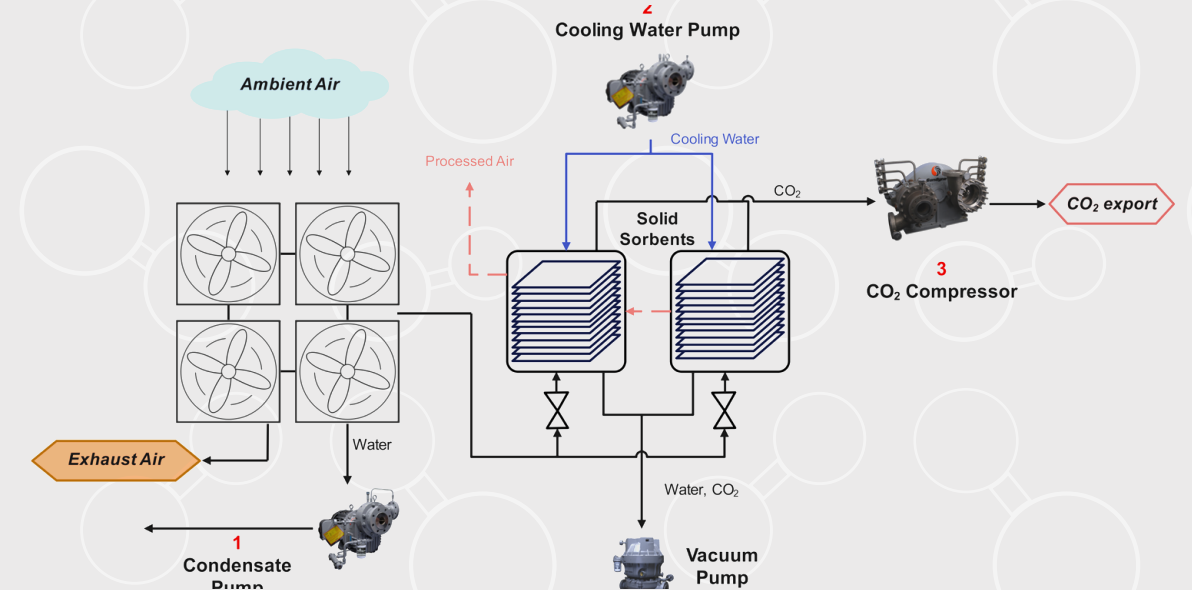
The pure CO₂ stream is then ready to be exported. A CO₂ compressor is used to increase the pressure to a supercritical state to improve the efficiency of transportation of the CO₂. Like other types of carbon capture, the CO₂ can now be permanently sequestered underground or sent to another industrial facility for utilization as a feedstock.

DAC with a Liquid-sorbent



Location	Service	Equipment Type	Medium
1	Sorbent Pump	HMD, LMV, Marelli	Liquid sorbent (KOH, other hydroxides)
2	Sorbent Make-up Pump	HMD, LMV, Marelli	Liquid sorbent (KOH, other hydroxides)
3	Carbonate Pump	LMV, Marelli	Carbonate slurry (K ₂ CO ₃ , other carbonates/bicarbonates)
4	Condensate Pump	Sunflo	Water
5	Reboiler Recirculation Pump	Sunflo, LMV	Water
6	CO ₂ Compressor	LF-2000, LMC, BMC	CO ₂

DAC with a Solid-sorbent

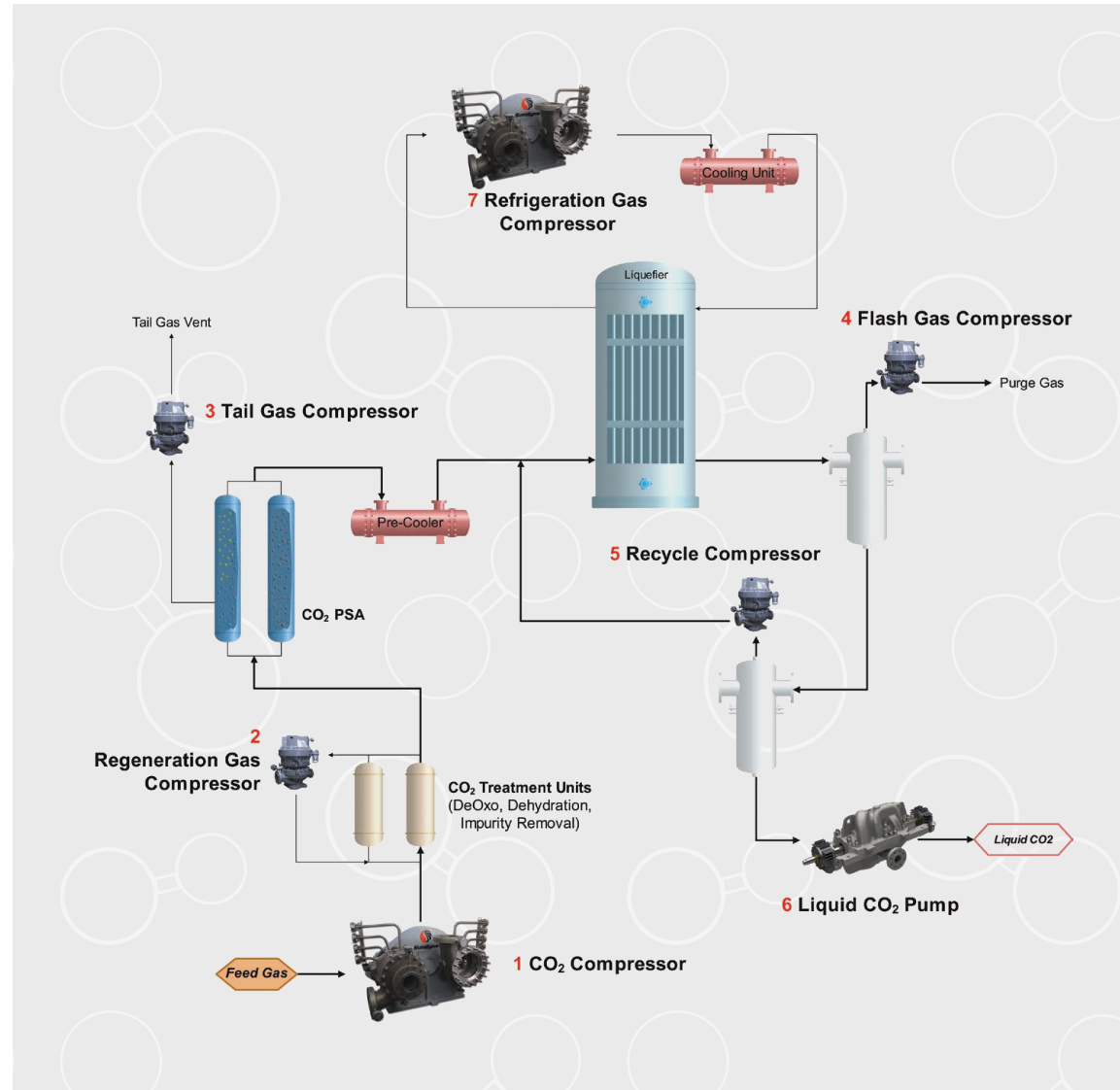


Location	Service	Equipment Type	Medium
1	Condensate Pump	Sunflo	Water
2	Cooling Water Pump	Sunflo, LMV	Water
3	CO ₂ Compressor	LF-2000, LMC, BMC	CO ₂

CO₂ Liquefaction

CO₂ can be liquefied before being transported in pressurized tanks on ships, rail or by truck. Liquefied CO₂ (LCO₂) carriers are used for the transport of CO₂ over long distances when pipelines are infeasible.

The CO₂ liquefaction process requires a series of compressors and cooling steps to liquefy the CO₂ and remove any water and impurities. Compressing CO₂ into a supercritical state makes it denser and more economical to transport CO₂. Pumps are used to load the liquid CO₂ into the ship's storage tanks and to unload it at the destination. On the receiving end (after shipping), the CO₂ is typically stored in a liquid state before a vaporization or regasification process. These pumps must handle CO₂ at low temperatures and high pressures.



Location	Service	Sundyne Equipment	Medium
1	Feed Gas Compressor	LF-2000	Flue Gas
2	Regeneration Gas Compressor	LMC/BMC or LF-2000	CO ₂ , Water
3	Tail Gas Compressor	LMC/BMC	Hydrocarbons, Water
4	Flash Gas Compressor	LMC/BMC	O ₂ , Ar, N ₂ , NO, CO
5	Recycle Gas Compressor	LMC/BMC	CO ₂
6	CO ₂ Pump	LMV	Liquid CO ₂
7	Refrigerant Gas Compressor	LF-2000	NH ₃ or other Refrigerant Gases

CO₂ Utilization

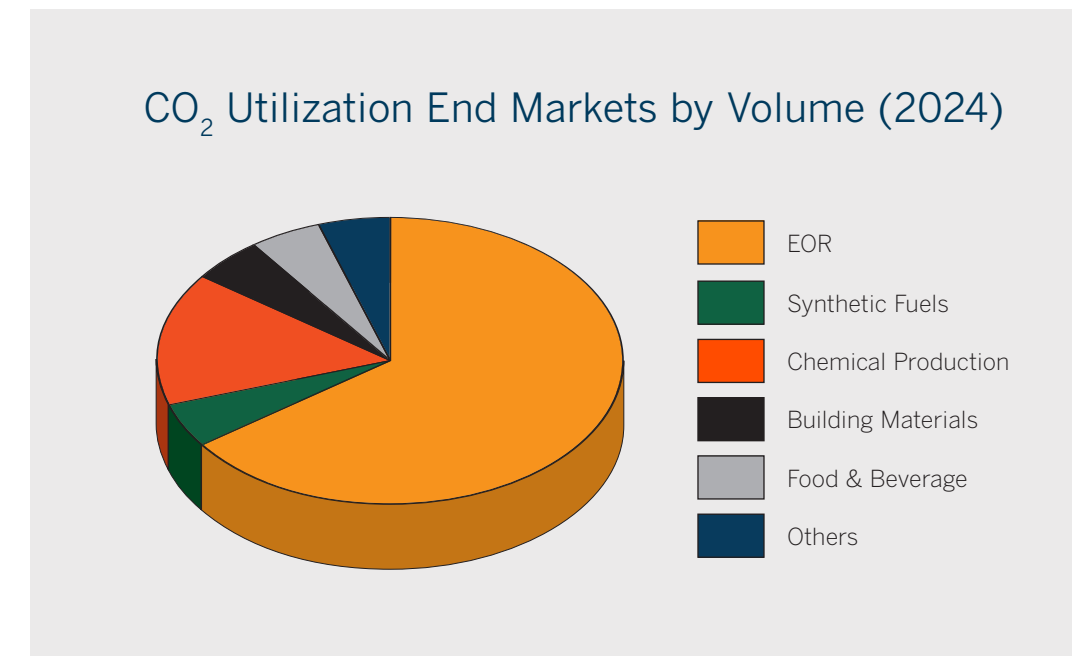
Today, the majority of announced carbon capture projects plan to permanently sequester the captured CO₂ in either saline aquifers or oil and gas reservoirs. In the future, CO₂ utilization markets will offer an additional value-stream by turning a waste product into a valuable commodity or feedstock.

The challenge is that few commercial processes exist at large-scales to transform CO₂ into useful products, and these processes are typically much more expensive than the incumbents. There are also infrastructure limitations in transporting CO₂ to new end-use outlets. Today, CO₂ pipeline infrastructure is largely built for permanent storage or enhanced oil recovery. Therefore, new transportation networks will need to be built to as CO₂ utilization markets develop.

The key markets for CO₂ utilization include:

- **Enhanced oil recovery:** injecting CO₂ into depleting oil fields to increase recovery rates
- **Synthetic fuels:** using CO₂ as a feedstock to produce renewable fuels, such as methanol
- **Chemical production:** using CO₂ as a feedstock to produce chemicals, such as urea, salicylic acid, and polymers
- **Building materials:** embedding CO₂ in concrete during curing or in synthetic aggregates
- **Food and beverage:** using CO₂ for carbonization or in packaging to extend shelf-life
- **Others:** Algae Cultivation, Agriculture, Wastewater Treatment

CO₂ Utilization End Markets by Volume (2024)



This brochure highlights synthetic methanol production as a fast-growing CO₂ utilization market. There is an increasing demand for sustainable fuels driven by global compliance and voluntary markets. Synthetic methanol can be used directly as a marine fuel, can be blended with gasoline, and can also be used in several industrial processes to reduce carbon intensity. Producing synthetic methanol involves carbon capture, hydrogen production, methanol synthesis, and methanol purification.

E-Methanol Production

1 Carbon Capture:

CO₂ is a feedstock for synthetic methanol production. As described in this document, CO₂ can be captured from industrial and power generation emissions through a variety of carbon capture technologies. Once captured, the CO₂ needs to be compressed typically between 30 and 100 bar for efficient reaction with hydrogen in methanol synthesis.

2 Hydrogen Production:

Hydrogen is also a feedstock for synthetic methanol production. The production method and carbon-intensity of the hydrogen input determines the categorization of the resulting methanol product. **Blue methanol** is produced from **blue hydrogen** (i.e., hydrogen produced from natural gas using reforming with carbon capture). **Green methanol** is produced from **green hydrogen** (i.e., hydrogen produced from splitting water into hydrogen and oxygen through electrolysis using renewable electricity).

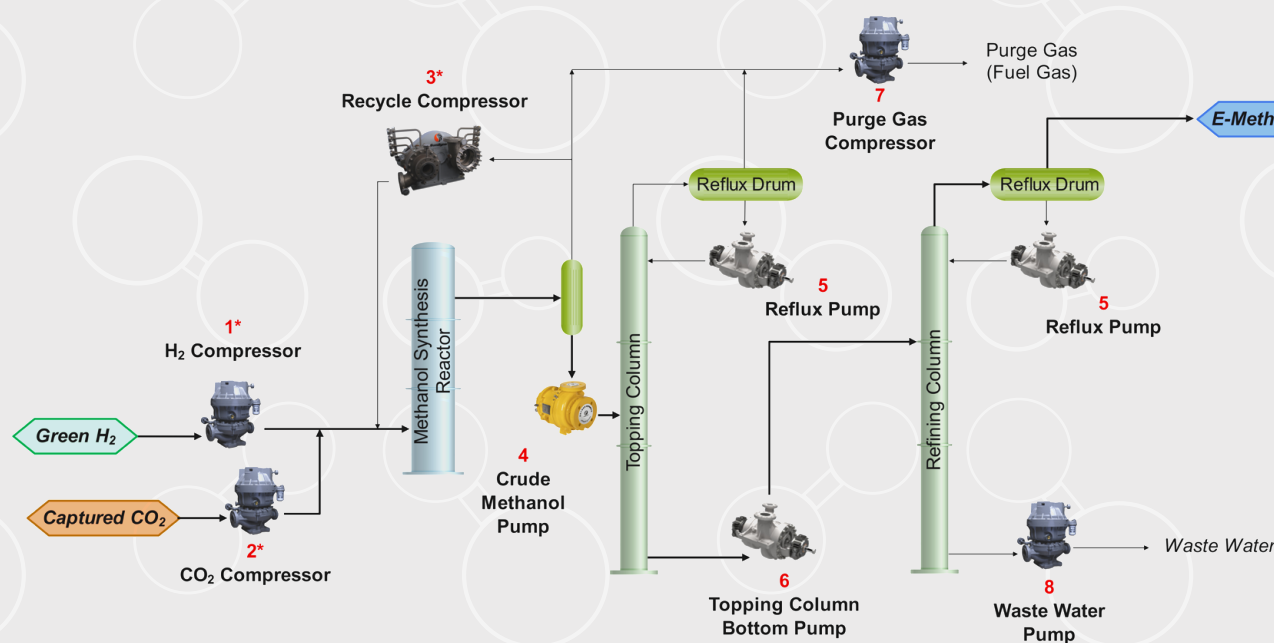
3 Methanol Synthesis:

Methanol is an intermediate product for producing other chemical products such as acetic acid, formaldehyde, dimethyl terephthalate, methyl tert-butyl ether, etc.

Compressed CO₂ and hydrogen are mixed and fed into a reactor where a catalyst is introduced. The following chemical reaction occurs within the reactor, producing methanol and water:



After the reaction occurs, the mixture is cooled to condense the water and methanol. Any residual CO₂ and H₂ is separated and recycled back into the reactor. Then, the liquid methanol is separated from the water in two distillation columns and the methanol product is sent to storage tanks for distribution and use.

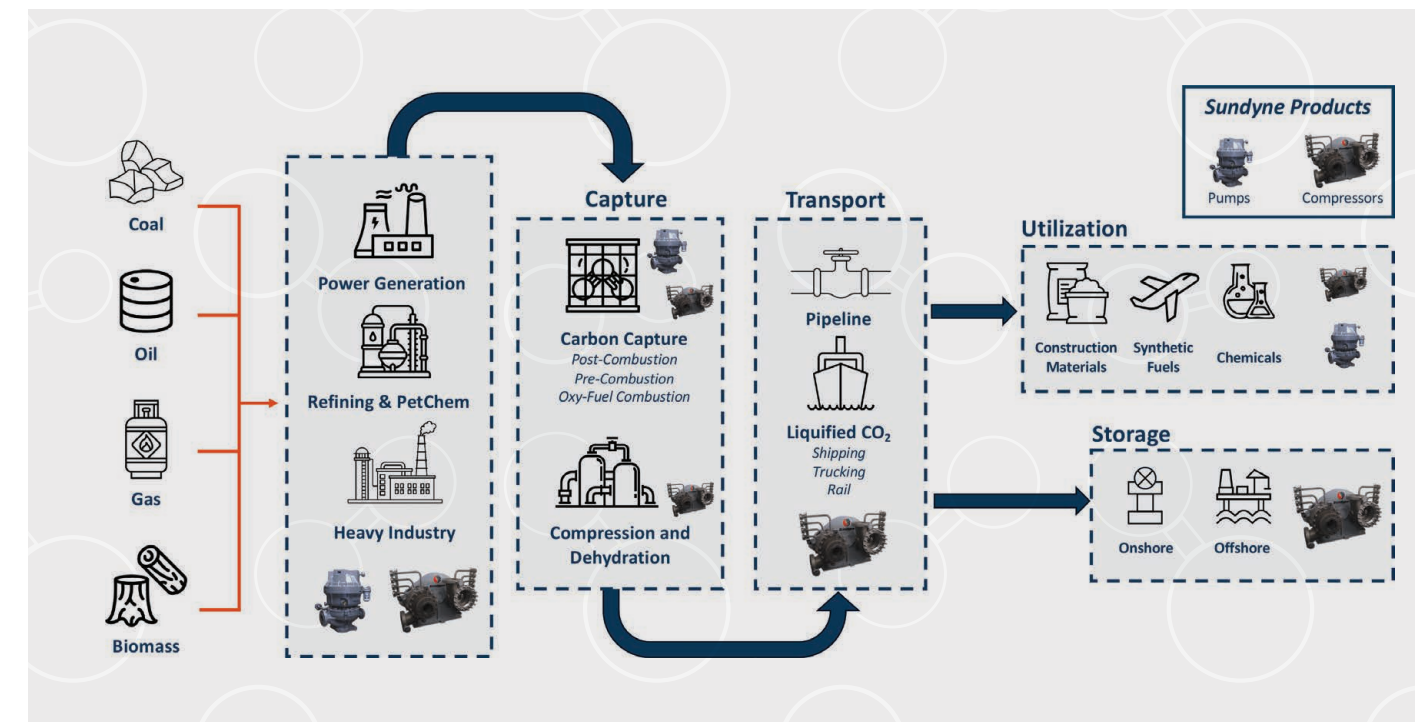


Location	Service	Equipment Type	Medium
1*	Hydrogen Compressor	LMC/BMC or LF-2000	Hydrogen
2*	CO ₂ Compressor	LMC/BMC or LF-2000	CO ₂
3*	Recycle Compressor	LMC/BMC or LF-2000	Proc CO and CO ₂
4	Crude Methanol Pump	HMD	Methanol and Water
5	Reflux Pump	Marelli or LMV	Water and Methanol
6	Bottom Pump	Marelli or LMV	Methanol and Water
7	Purge Gas Compressor	LMC/BMC	CO, CH ₄
8	Waste Water Pump	Marelli	Water

* Sundyne integrally-g geared compressors offer the flexibility to combine services 2, 3 and 4 on a single machine with a shared base plate and motor.

CCUS Value Chain

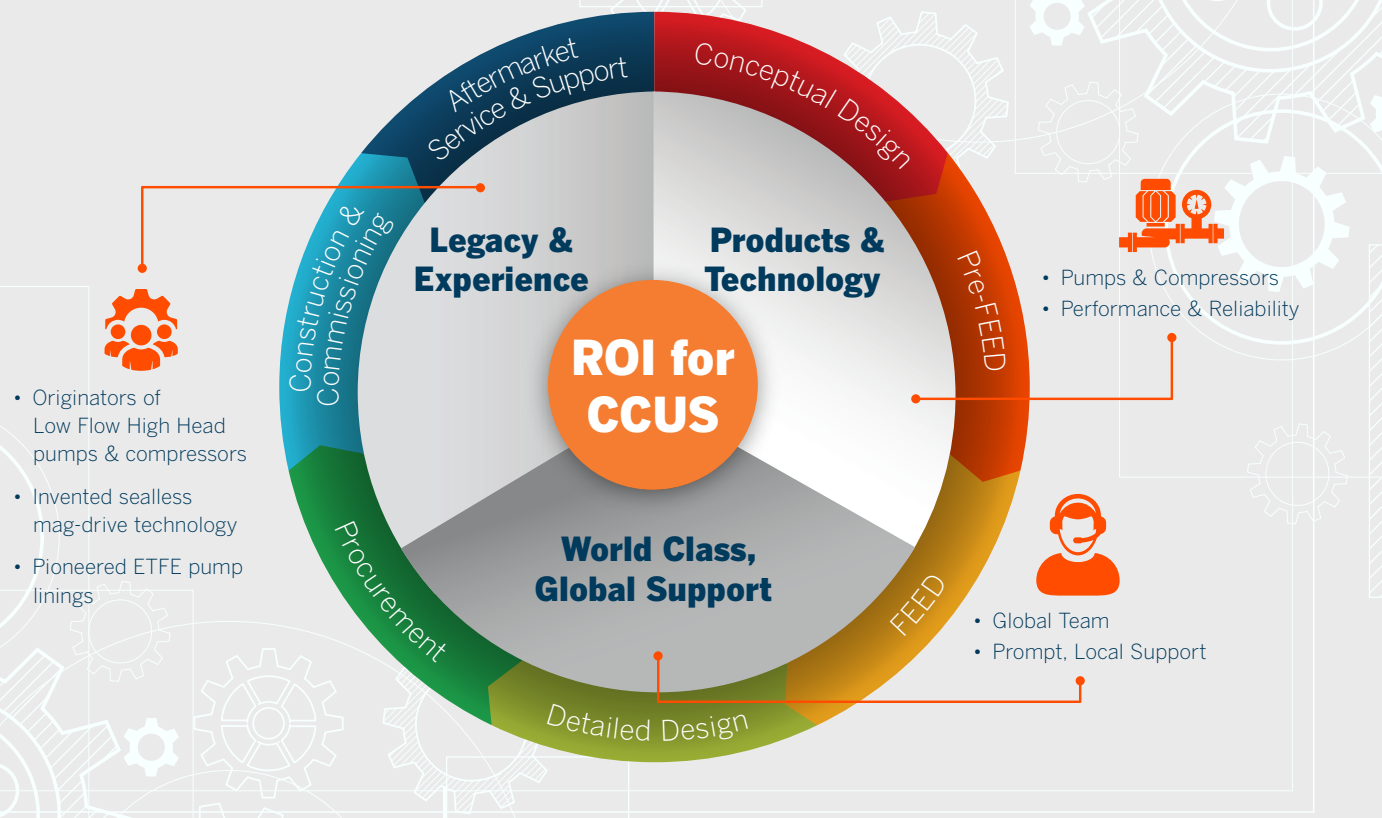
Sundyne has a range of products that serve the entire CCUS value-chain. To learn more about the Sundyne family of precision-engineered pumps and compressors, please visit www.sundyne.com.



Sundyne's Value Proposition for Carbon Capture

Sundyne's unique combination of technology, expertise and support provides a 360-degree, full lifecycle service that spans everything from project pre-FEED to comprehensive 24x7 support, utilizing a global network of Authorized Service Centers and aftermarket specialists.

Total Product Lifecycle, 360° Service



Sundyne Compressors



Sundyne's Integrally-Geared Compressor line features a robust and compact design with an integrated gearbox that runs multiple stages, resulting in space-saving installations. In CCUS applications, efficient and reliable compression of CO₂ is critical for the success of projects. Sundyne compressors offer improved efficiency and precise control of operating conditions based on a full scope responsibility including process controls. With modularization of packaged solutions, Sundyne offers reduced lead-times and optimizes the total cost of a compression unit. Sundyne compressors, available from standard to full API compliant configurations, can operate continuously for up to 5 years without requiring maintenance or service.

Sundyne LMV and HMP Pumps



Sundyne integrally geared centrifugal pumps are optimized for low flow-high head applications. They offer the best efficiency in the low flow range with a proven track record of high reliability. A single impeller in a Sundyne LMV pump spins at high speed to produce the same head as a multistage pump running at synchronous speed. Sundyne LMV pumps are ideally suited for services such as boiler feed water pumps, condensate pumps, solvent circulation pumps and reflux pumps. To achieve even higher heads, two or more integrally geared stages run in series in Sundyne HMP pumps. Such pumps can be used in liquid CO₂ injection applications. The compact design reduces installation cost, and the simplicity limits the number of spare parts while making maintenance easier.

Marelli Pumps



Marelli pumps leverage a track record of more than 60 years in centrifugal pump design, development, manufacturing and service. Marelli caters to global markets from conventional oil & gas and petrochemicals to fast-evolving Clean Energy segments, including green/blue hydrogen, ammonia, carbon capture, and renewable fuels processing. Marelli covers a wide range of API 610 in OH, BB and VS types to meet stringent customer specifications.

Sealless Magnetic Drive Pumps – HMD and ANSIMAG



Sundyne sealless pumps provide optimum safety and environmental protection for a wide range of applications in carbon capture and CO₂ utilization. They are designed for hazardous and corrosive liquids, and applications that are difficult to seal. HMD Kontro metallic and Ansimag ETFE-lined sealless pumps ensure total product containment, increased reliability and uptime and simplified maintenance with no seals or seal support systems, whilst meeting industry standards such as ASME, ISO and API

Sunflo Pumps



Sundyne Sunflo pumps are Fit for purpose, Industrial grade pumps designed for Low flow – High head applications, such as boiler feed water, condensate, and demineralized water circulation. The design development of Sunflo range pumps is built on Sundyne knowledge and experience of its API integrally geared pumps. A single impeller runs at high speed to produce high heads in a very compact and reliable design. The close coupled configuration eliminates alignment, simplifies installation while further reducing footprint. The Sunflo cartridge shaft assembly comes complete with all the rotating parts and enables quick and easy servicing of the pump in-place.

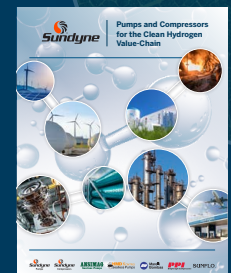
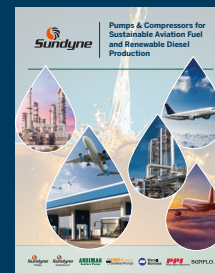
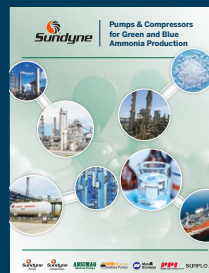
When it comes to CCUS applications, Sundyne is the **Safer, Better, Best** choice.

Safer for Operations
Better for the Environment
Best Total Lifecycle Value

For more information please visit www.sundyne.com and fill out the Contact Me form. A Sundyne representative will contact you.

For more information on Sundyne's product fit in Clean Energy Markets, refer to our other clean energy brochures:

- Green and Blue Ammonia Production
- Sustainable Aviation Fuel and Renewable Diesel
- Clean Hydrogen Value Chain



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