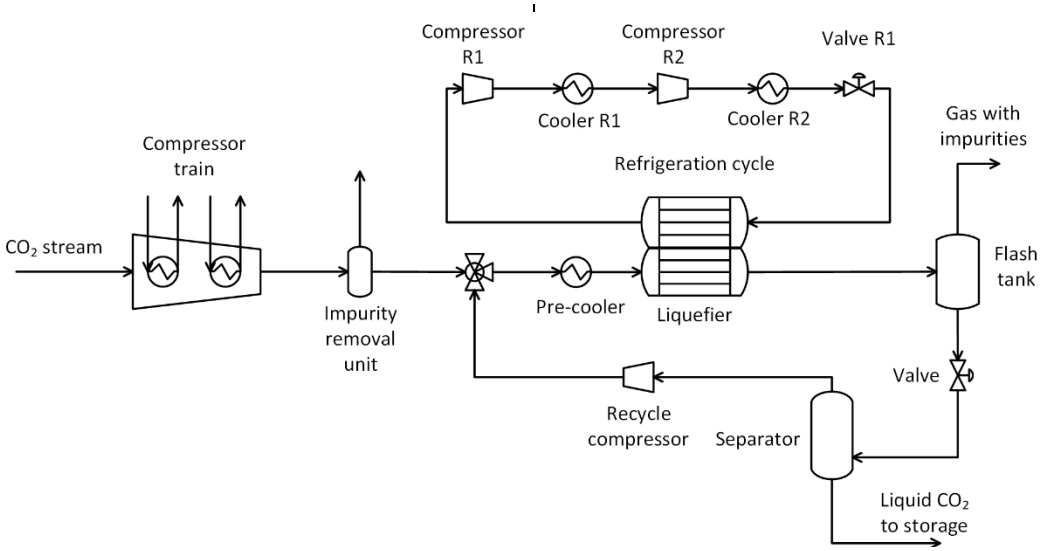
CO_2 Liquefaction

CO_2 liquefaction is the process of converting the gaseous CO_2 into its liquid form. This transformation is achieved through a series of compression and cooling stages, allowing CO_2 to be stored and transported more efficiently.[1] Liquefaction approach uses liquid pumps that require significantly less power to raise pressure and are considerably less expensive than gas compressors.[2] The CO_2 is compressed in the compression train in several stages to reach liquefaction pressure. When CO_2 is available at atmospheric pressure, 3-4 stages are required as opposed to high-pressure CO_2, where compression may not even be required. Between stages, intercooling and flash separators are used to remove condensed water. The CO_2 stream enters an impurity removal unit after the compression train, where any impurities are eliminated. It passes through a liquefier that is chilled by a refrigeration loop and a pre-cooler before condensing. The stream is totally condensed and slightly sub-cooled after passing through the liquefier if it is pure CO_2 or if all impurities are condensed at a high enough liquefaction pressure. The CO_2 stream may partially condense in the liquefier in cases when the inlet gas contains contaminants. To attain the desired delivery pressure level, the condensed liquid passes through a valve. The stream next passes through a separator, which recovers liquid CO_2 and sends it to buffer storage before being transported by ship. Before the pre-cooling phase, the outlet gas of the separator is compressed and recycled to be combined with the mainstream.



CO_2 liquefaction process

REMOVED COMPONENTS

- Water is removed as condensate after every compression stage.
- Other impurities, if any, are also removed before the liquefaction step.

FUNCTION IN CCU VALUE CHAIN

- Liquefy CO_2 for transportation either by shipping, truck, rail or pipelines. For shipping, the CO_2 may be compressed between 6.5-15 bar (low to medium pressure shipping, but requires sub-zero temperatures (-50 to -30 °C).[3] The typical transport temperature and the corresponding pressure in Northern lights project is -30 °C and 15-21 bar.[4]

LIMITATIONS

- The liquefaction approach necessitates CO_2 transportation at sub-zero temperatures.
- Careful assessment of the refrigeration process is critical in the liquefaction approach for accurate system power accounting.

ENERGY

- Electricity is consumed by the initial CO_2 compressors and the recycle compressor.
- Electricity is also consumed by the refrigeration cycle compressors.

CONSUMABLES

Cooling water is used for cooling in the CO_2 compression train and refrigeration cycle. It is generally recycled and not consumed.

Energy and consumables

Parameter	Value
Electricity (kWh/tCO_2)	90 - 96[5] *

Cooling water make-up (t/tCO_2)	0.4**

**Pure CO_2. Target transport pressure from 8 – 16 bar. Higher impurities result in higher electricity consumption.*
*** VITO study*

COSTS

The cost of CO_2 liquefaction is also variable depending upon the captured CO_2 purity and target transport pressure. The cost to liquefy at a scale of 1 MtCO_2/yr of pure CO_2 ranges from **€14 – €15 per tonne CO_2** at target transport pressures 8 – 16 bar.[5] For high-pressure liquefaction, mild cooling temperatures are sufficient. The cost to liquefy CO_2 at 66 bar at 20 °C using a flash and a distillation column was reported to **be €12 – €18 and €16 – €17 per tonne CO_2**, respectively.[6]

TECHNOLOGY PROVIDERS

- CO_2 liquefaction by **Linde**, Ireland.
- Cryocap™ LQ by **Air Liquide**, France.
- CO_2 liquefaction by **Baker Hughes**, USA.
- CarboPac-L by **Bright Renewables**, Netherlands.
- CO_2 liquefaction by **GEA**, Germany

ALTERNATIVE TECHNOLOGIES

Compression: CO_2 is compressed up to 80 bar and cooled to obtain the supercritical phase, and then pumped to pressures up to 150 bar. This CO_2 phase is more suitable for pipeline transport and does not require a refrigeration cycle.

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