Cryogenic CO_2 Separation from Flue Gas

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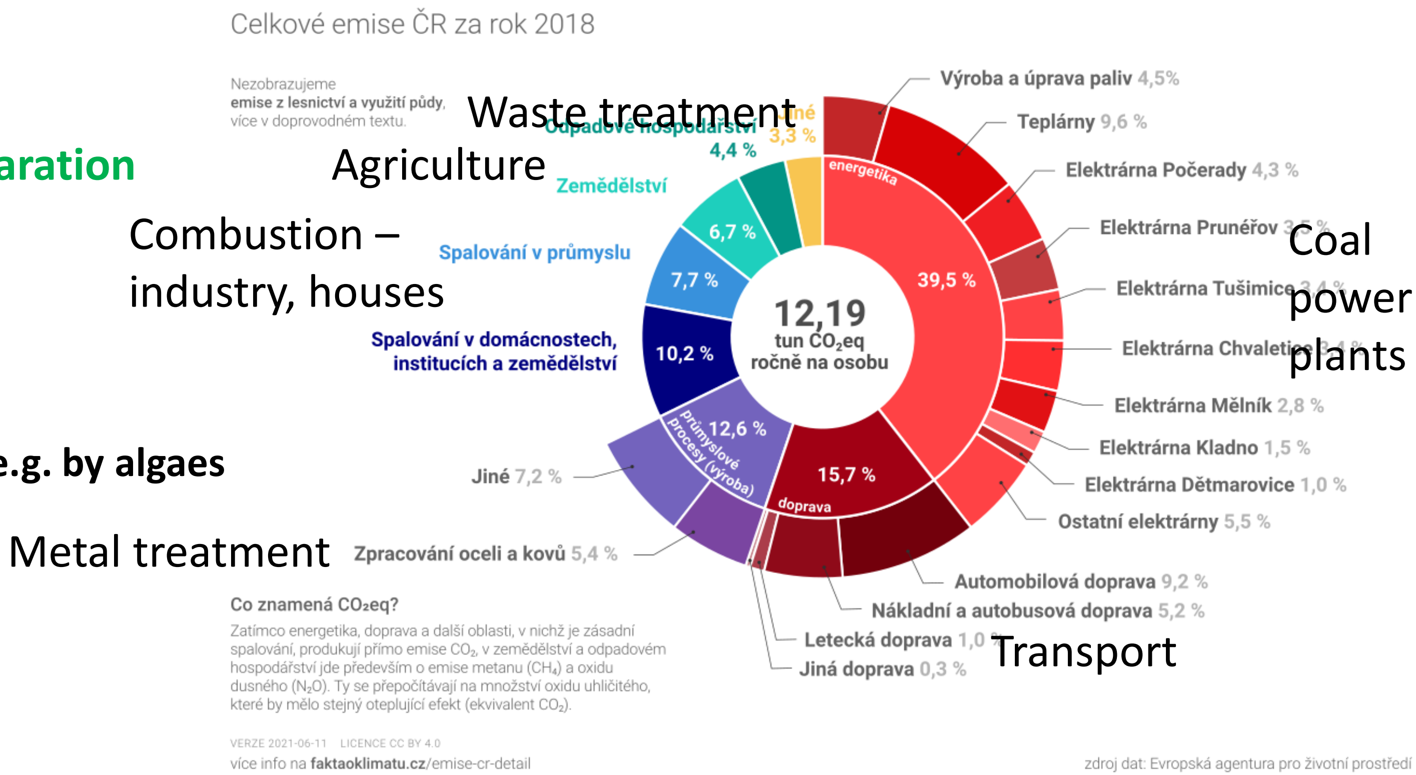
Decarbonization

Emissions of Greenhouse gases in Czech Republic - 2018

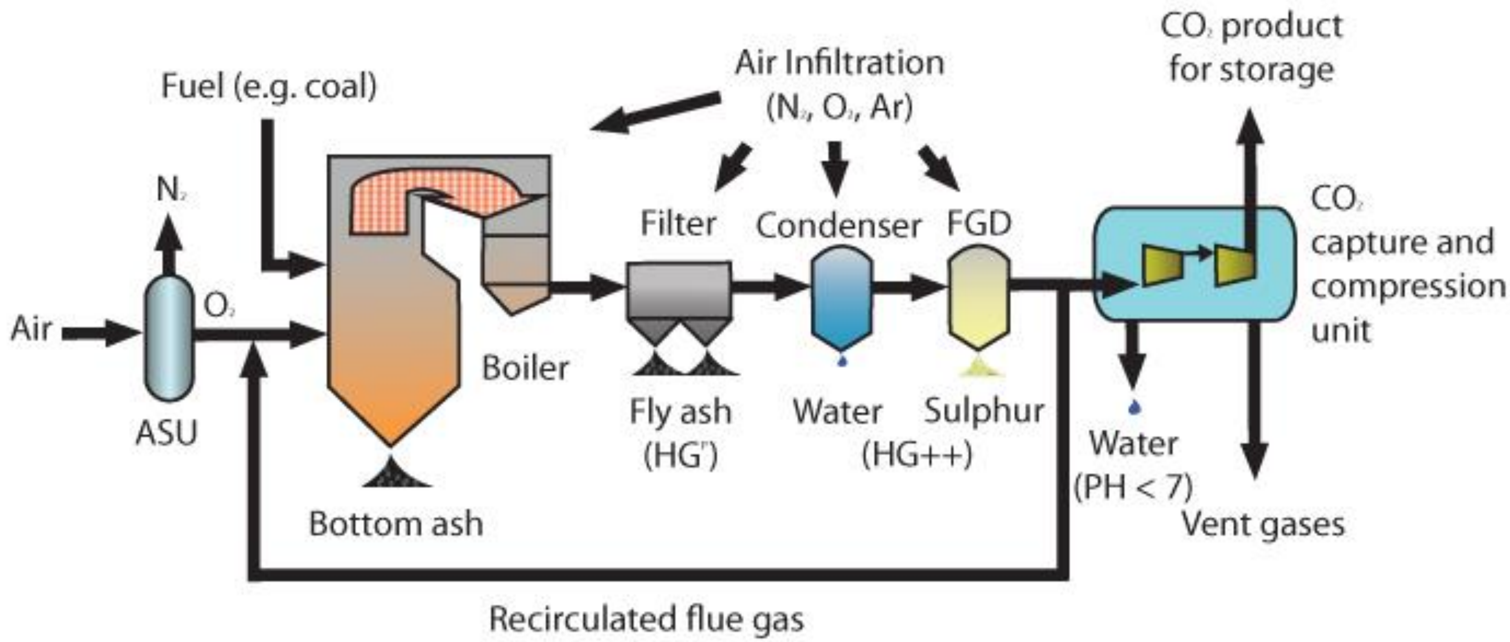
Technologies for CO_2 separation

- **Absorption**
- **Adsorption**
- **Membrane separation**
- **Cryogenic separation**
- **Biological separation – e.g. by algaes**



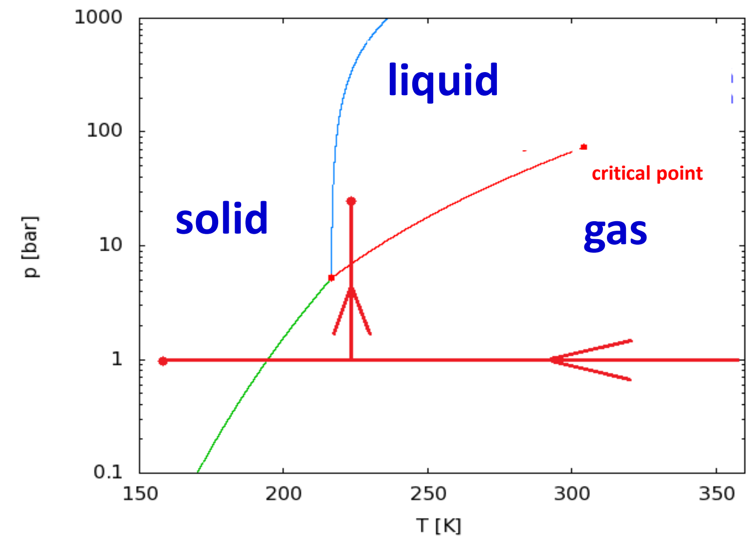
Strategies for CO_2 capture

- **post-combustion separation**
- **pre-combustion separation**
- **separation after oxy-fuel combustion**



Technologies for CO_2 separation

- **Absorption** η_{sep} = 85 % price = 40 – 100 USD/t_{CO2}
- **Adsorption** η_{sep} = 80 % price = 50 – 150 USD/t_{CO2}
- **Membrane separation** η_{sep} = 70 % price = 15 – 55 USD/t_{CO2}
- **Cryogenic separation** η_{sep} = 99.99 % price = 55 – 130 USD/t_{CO2}
- **Biological separation (by algae)**



FONT-PALMA, Carolina, David CANN a Chinonyelum UDEMU. Review of Cryogenic Carbon Capture Innovations and Their Potential Applications. C. 2021,7(3).

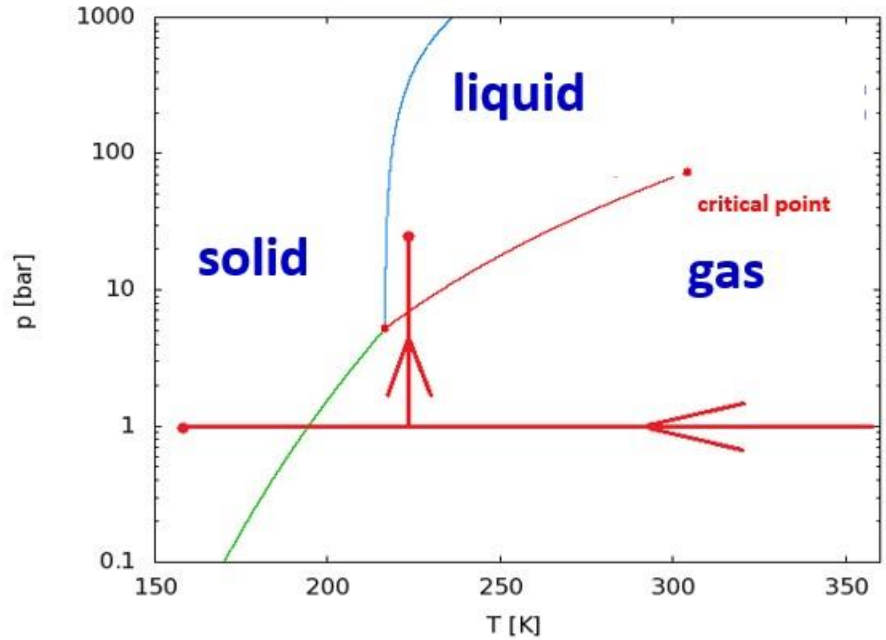
Cryogenic separation

Advantages

- High CO_2 purity
- High separation efficiency

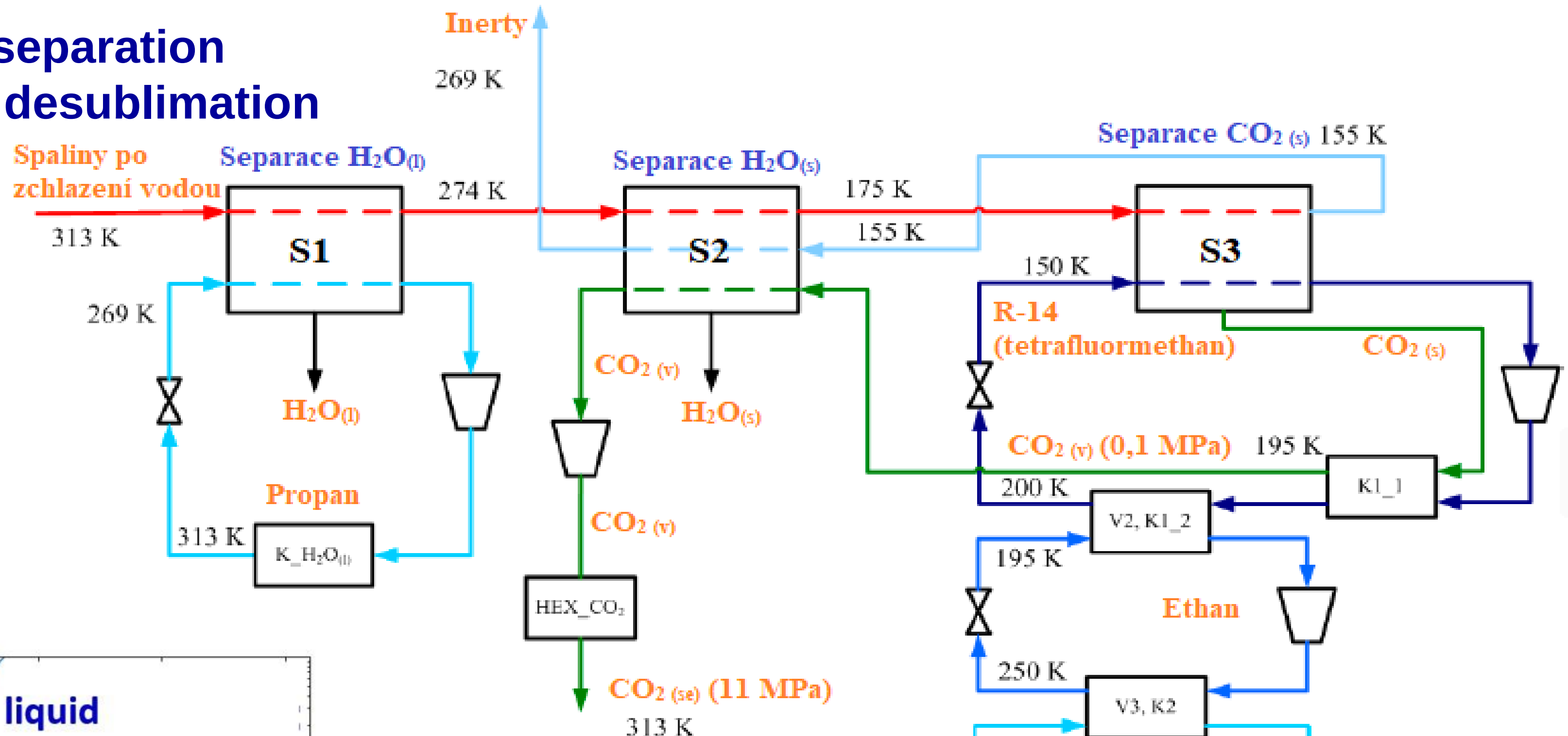
Disadvantages

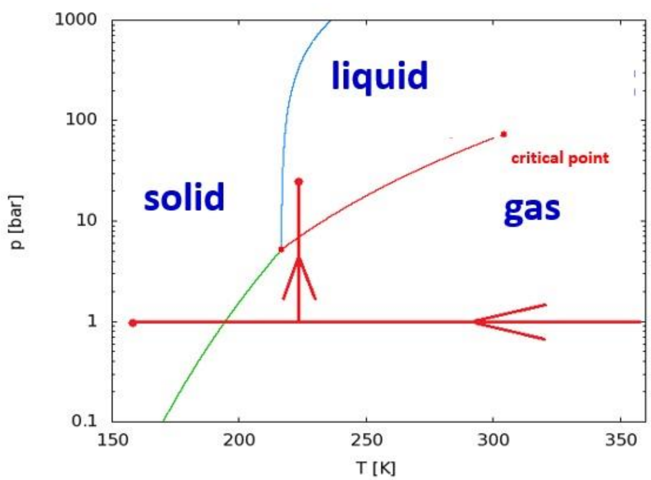
- High energy demanding technology
- Deep cold source is needed.
- Insulation & special materials are needed.
- Water separation is needed.



Triple point	
T [K]	p [bar]
216.55 K (-56.6 °C)	5.17

Cryogenic CO_2 separation by freezing and desublimation





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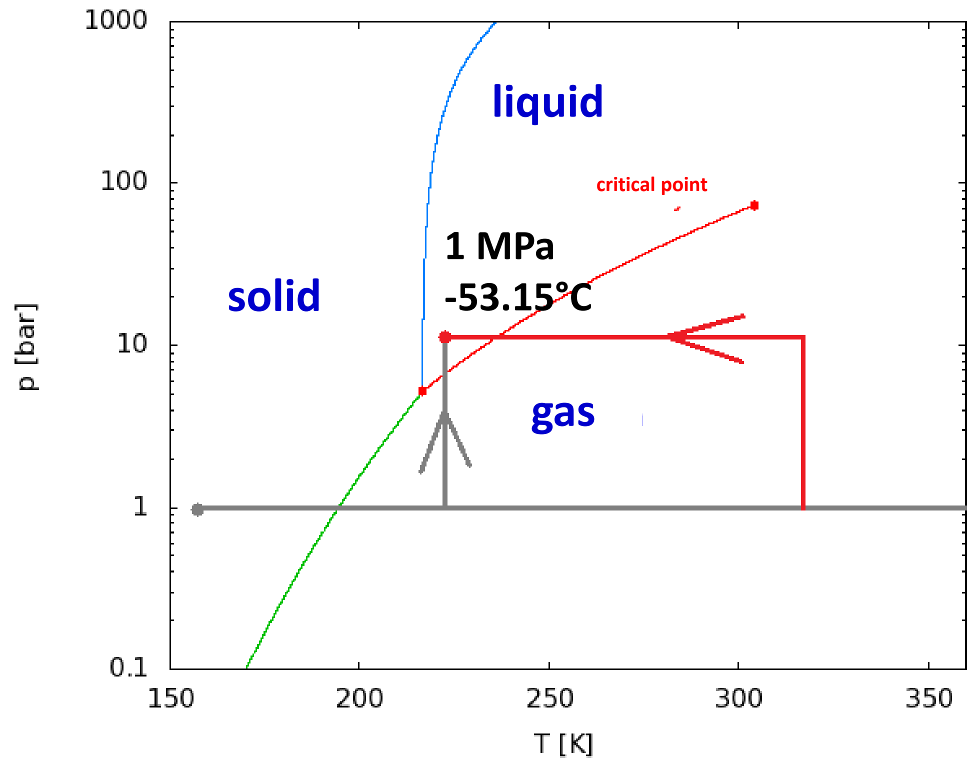
Motivation

1. Regasification of cryoliquids (e.g. LNG, LAES) ⇒ recovery of stored cold for CO_2 cryogenic separation.
2. CO_2 separation as a liquid.

⇒to decrease energy consumption

⇒to improve economy

Świnoujście LNG terminal
Polskie LNG @ Felinski-Piotr

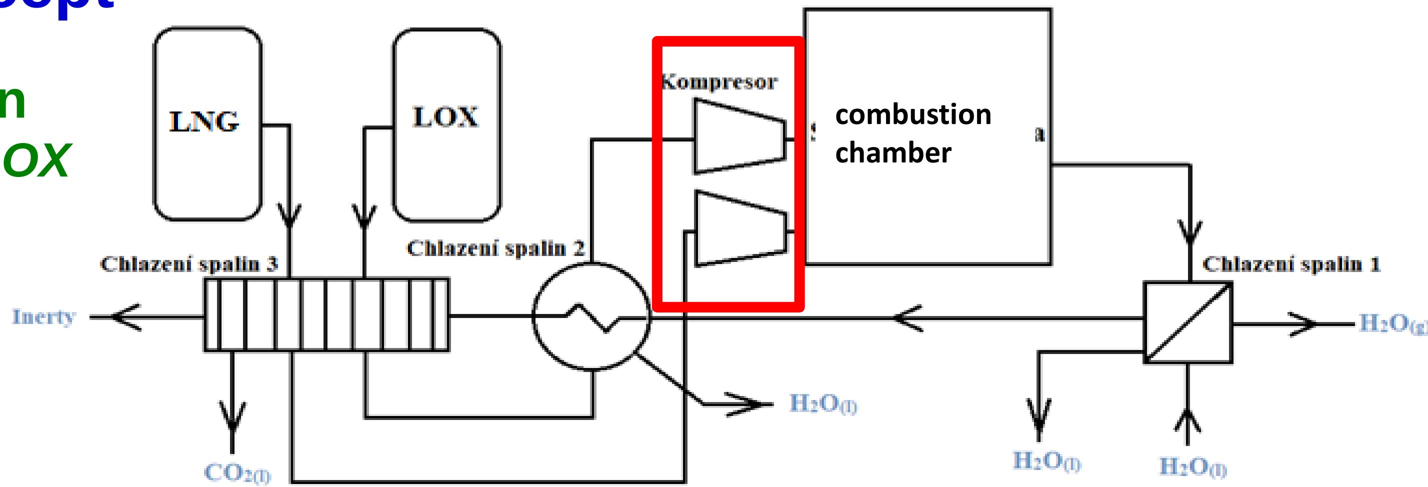


Technology concept

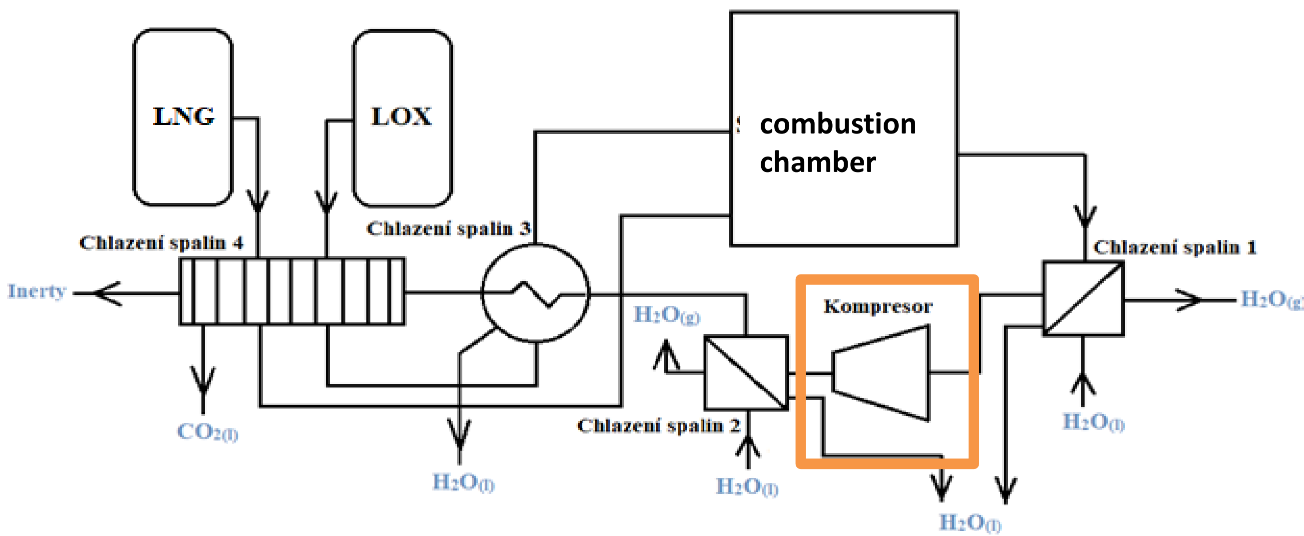
Oxy-fuel combustion

cold source: LNG or LOX

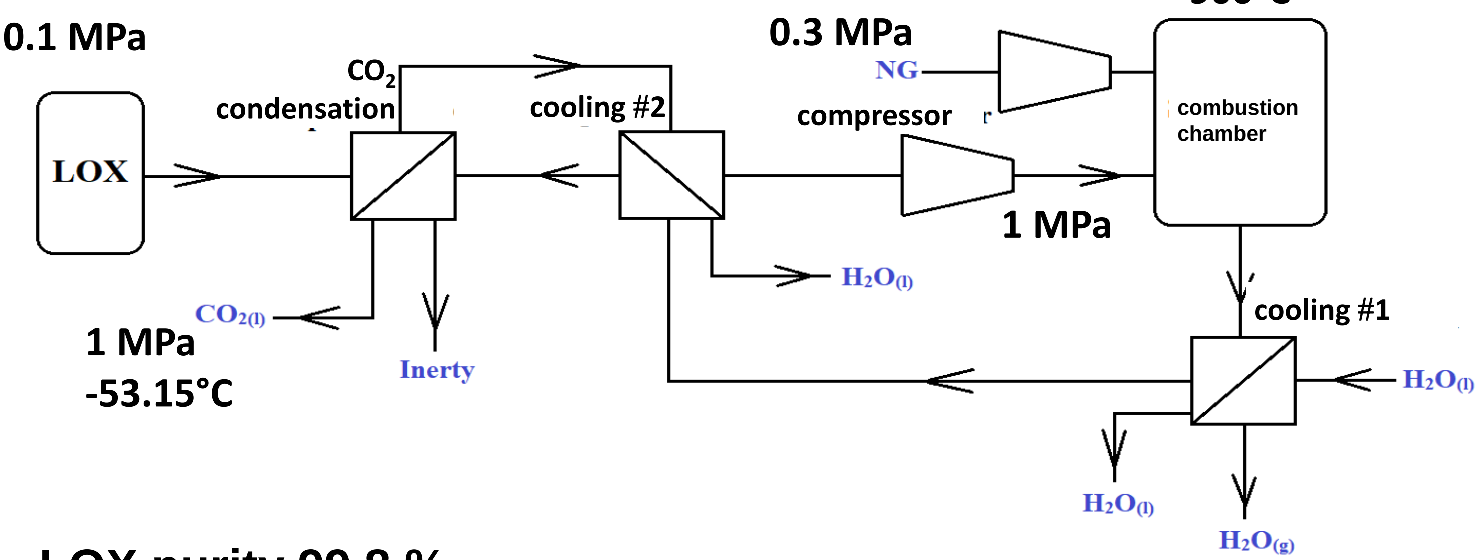
Pre-combustion compression



Post-combustion compression



1. Pre-combustion compression
(Pre-Comp)



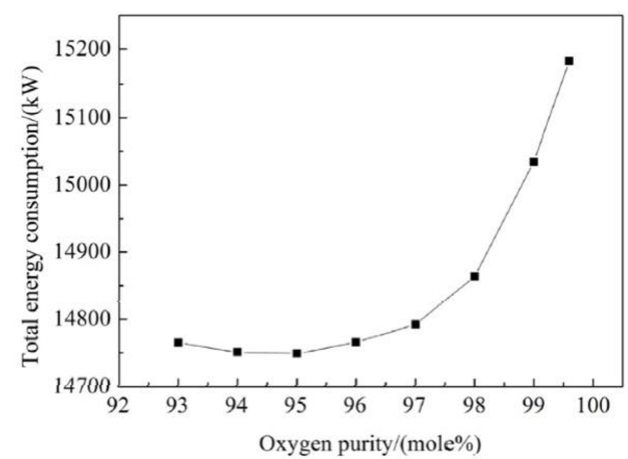
Effect of oxygen purity
Effect of oxygen excess

Pre-Comp 99.8 - LOX purity 99.8 %

Pre-Comp 100 - LOX purity 100 %

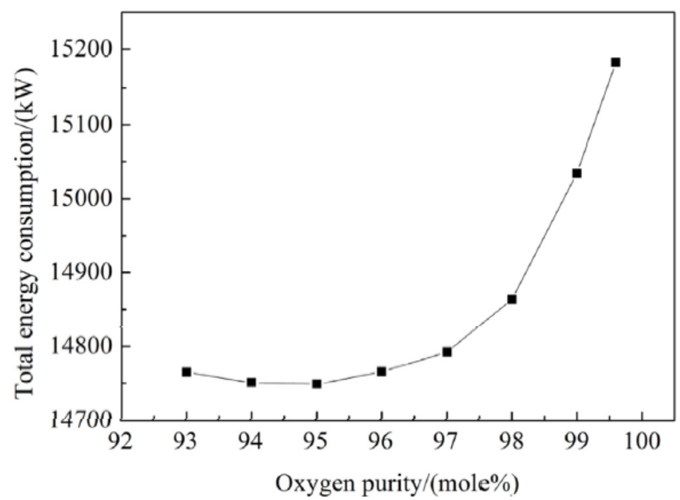
Pre-Comp 95 - LOX purity 95 %

Pre-Comp 95 205/1.6 - LOX purity 95 %
flue gas T = 205K, 1.6 MPa



Effect of oxygen purity

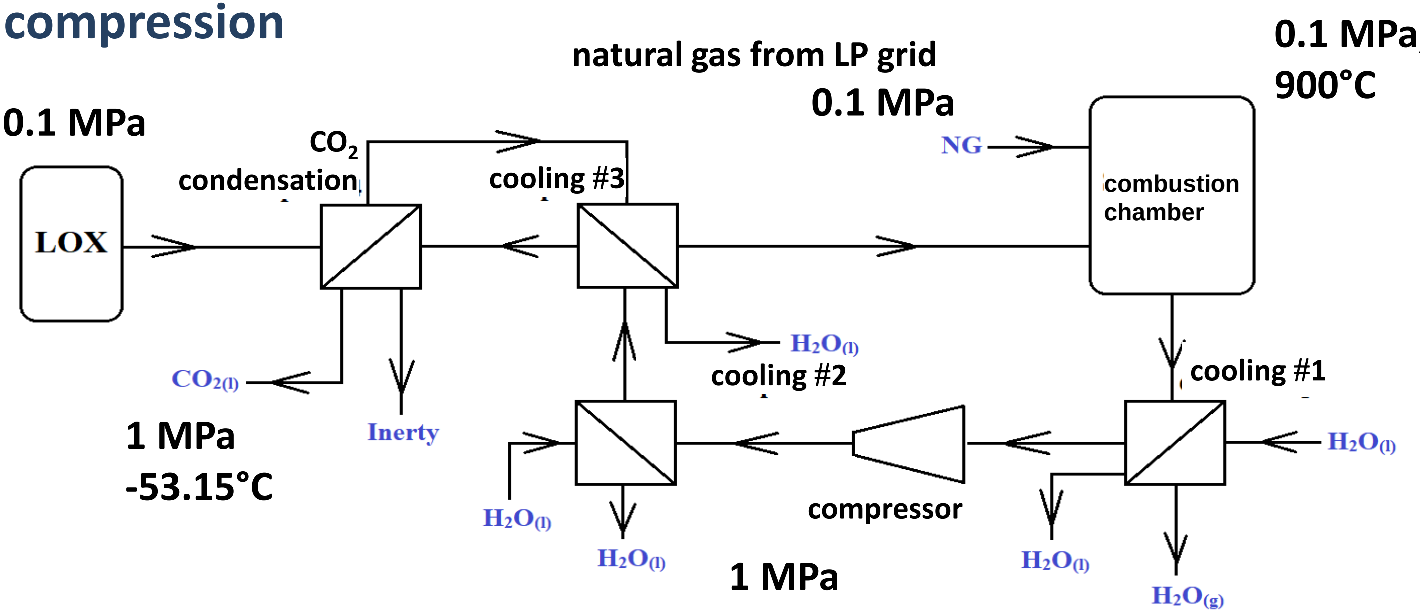
Oxyfuel combustion: oxygen of 95 % purity is usually utilized (cheaper)

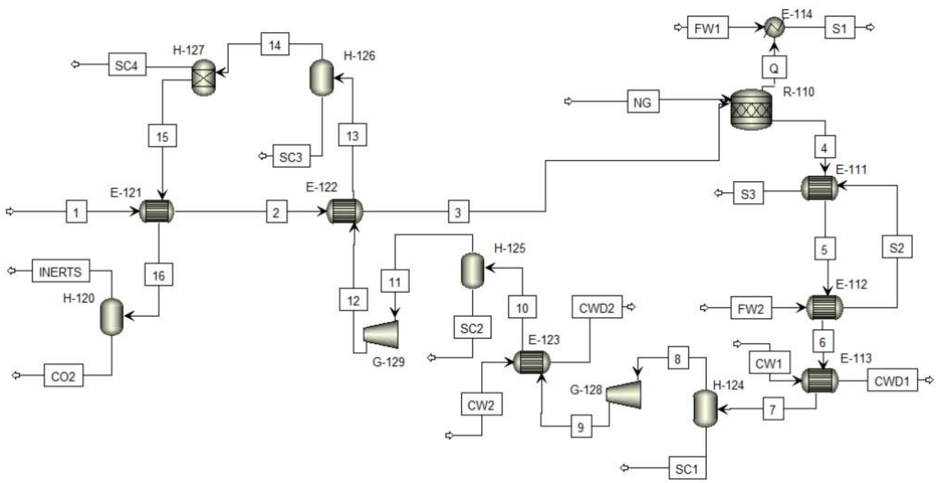


Cryogenic air separation

LOX purity [%]	Flue gas temperature [K]	Pressure [MPa]	Separation efficiency [%]	LCO2 purity [%]
95	220	1	84.5	98.5
	205	1	96.1	97.24
	220	1.5	94.1	96.74
	205	1.6	98.4	95
99.8	220	1	99.68	99.14
100	220	1	99.99	99.33

2. Post-combustion compression
(Post-Comp)

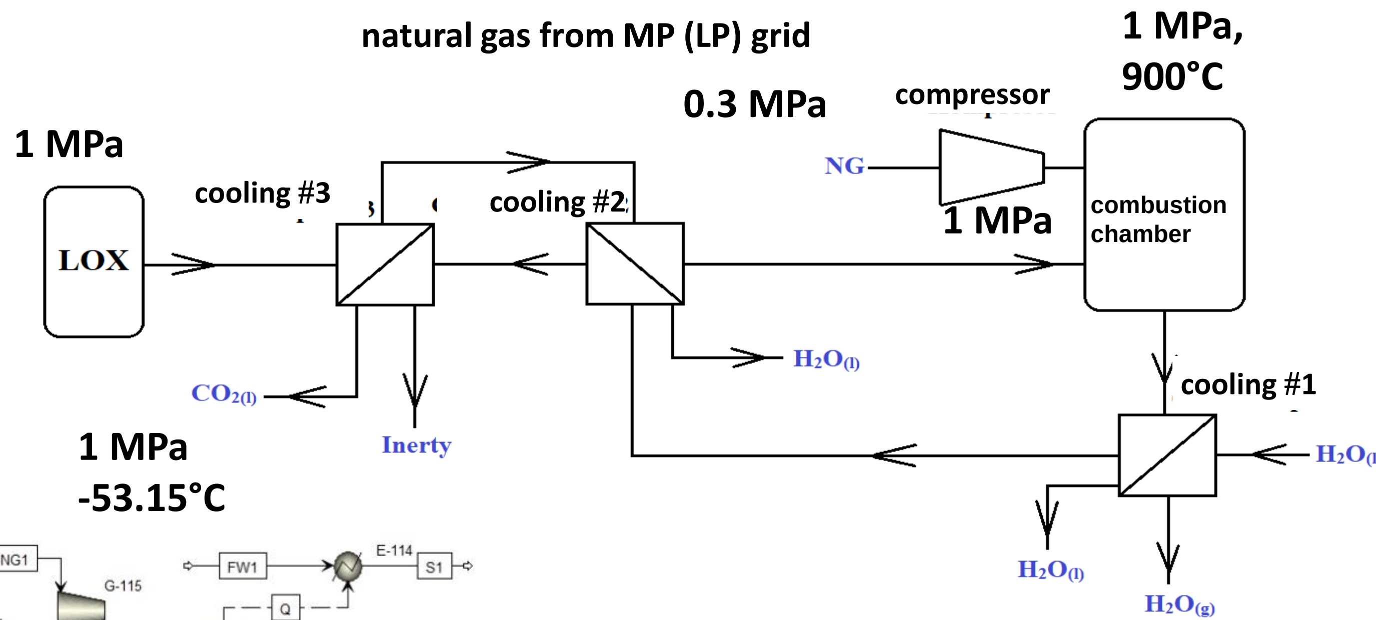


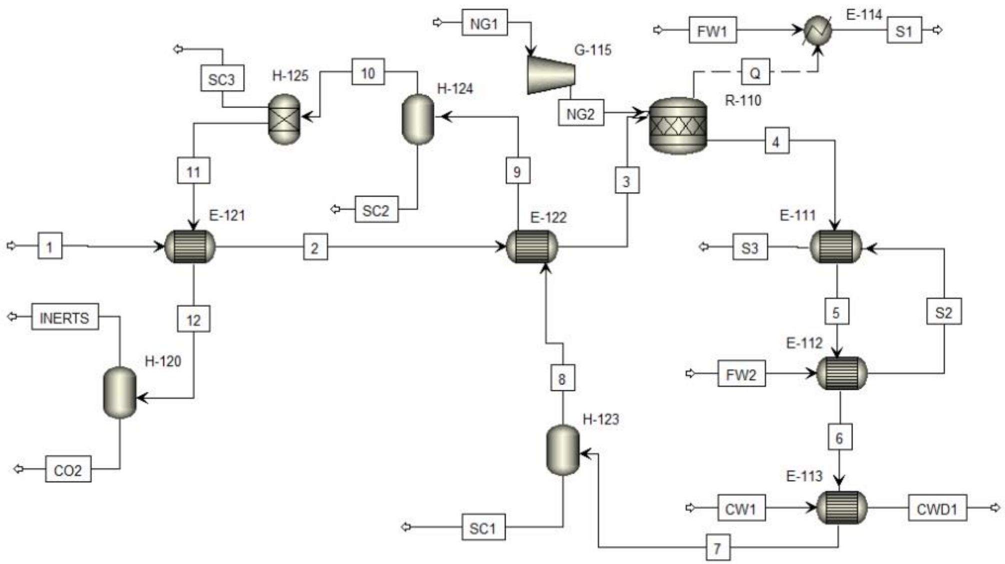


protection against water freezing
H127 – adsorption water dryer

3. No compression
(No-Comp)

LOX storage tanks up to 1.7 MPa
⇒ pressurized LOX





protection against water freezing
H125 – adsorption water dryer

Results

present technology: efficiency and purity > 99.9 %

Technology	Separation efficiency [%]	CO_2 purity [%]	Compressor input [kW]	Steam production [t/h]
Pre-Comp 99.8	99.68	99.14	221	12.29
Pre-Comp 100	99.99	99.3	244	12.28
Pre-Comp 95	84.59	98.5	185	12.21
Pre-Comp 95 205/1.6	98.43	95	287	12.27
Post-Comp	99.68	99.14	141	12.20
NoComp	99.68	99.14	-	12.12

Conclusions

present technology: efficiency and purity > 99.9 %

- The technology proposed combines oxy-fuel combustion and cryogenic CO_2 separation. The liquefied oxygen (LOX) is used as a oxygen source for combustion.
- The cold stored in LOX is utilized during regasification for CO_2 cryogenic separation. CO_2 is separated as a liquid (1 MPa, -53.15°C)
- The three technology concepts were analysed: 1) pre-combustion compression of NG and GOX, 2) post-combustion compression of flue gases, and 3) pressurized LOX (no compression).
- Pre-combustion compression: CO_2 efficiency 99.68 % + 99.14 % purity for 99.8 oxygen ; effect of oxygen purity η_{CO2} ↓, effect of oxygen excess η_{CO2} ↓. η_{CO2} improvement: T ↓, P ↑.
- Post-combustion compression: CO_2 efficiency 99.68 % + 99.14 % purity for 99.8 oxygen, lower steam production.
- Pressurized LOX: CO_2 efficiency 99.68 % + 99.14 % purity for 99.8 oxygen, lower steam production.

Thank you very much for your attention.

Acknowledgements

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