Integration of Oxygen-containing Exhaust Gas into the Air Separation Unit of an Oxyfuel Power Plant with Maximised CO_2 Capture Rate

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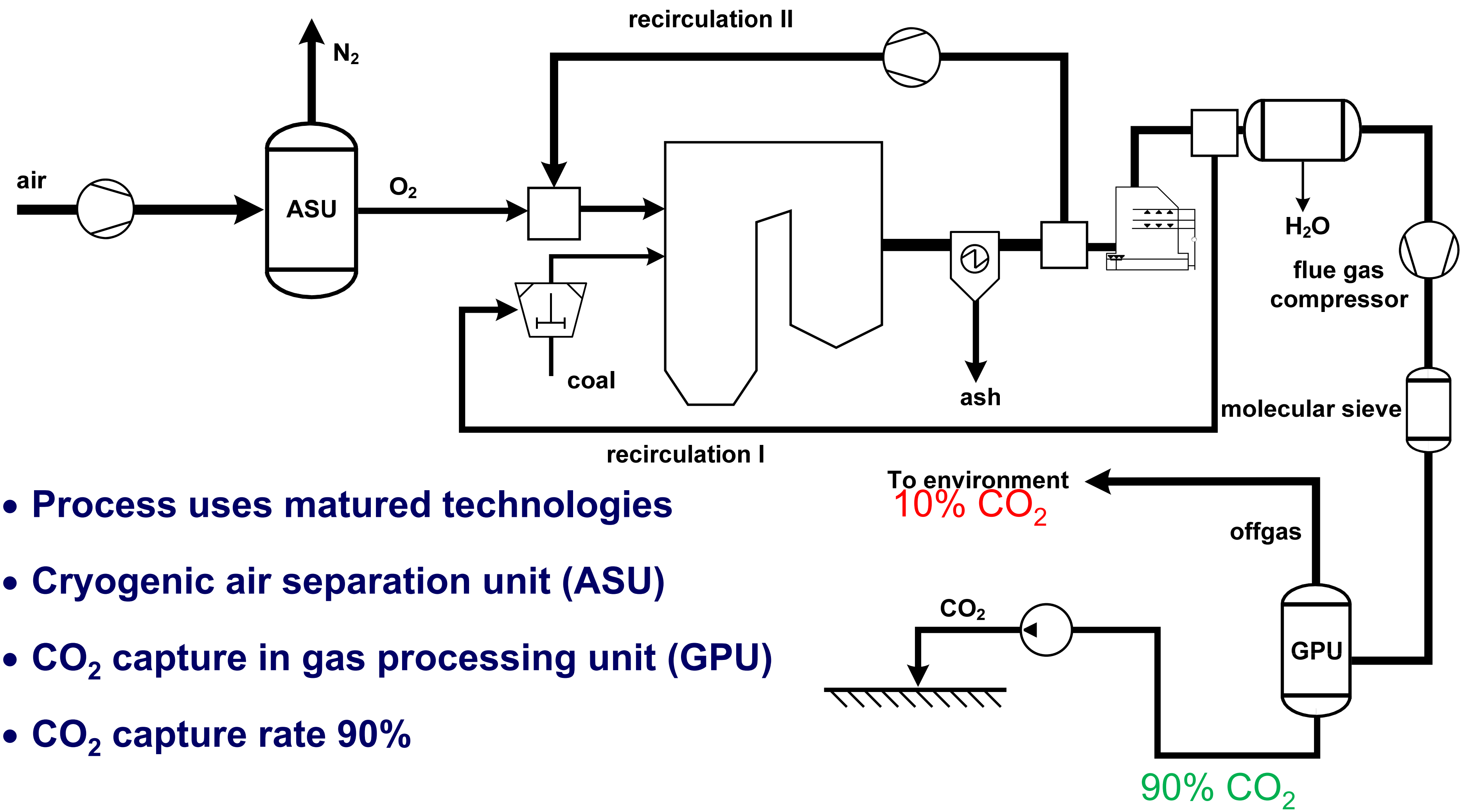

- **Process uses matured technologies**
- **Cryogenic air separation unit (ASU)**
- **CO_2 capture in gas processing unit (GPU)**
- **CO_2 capture rate 90%**

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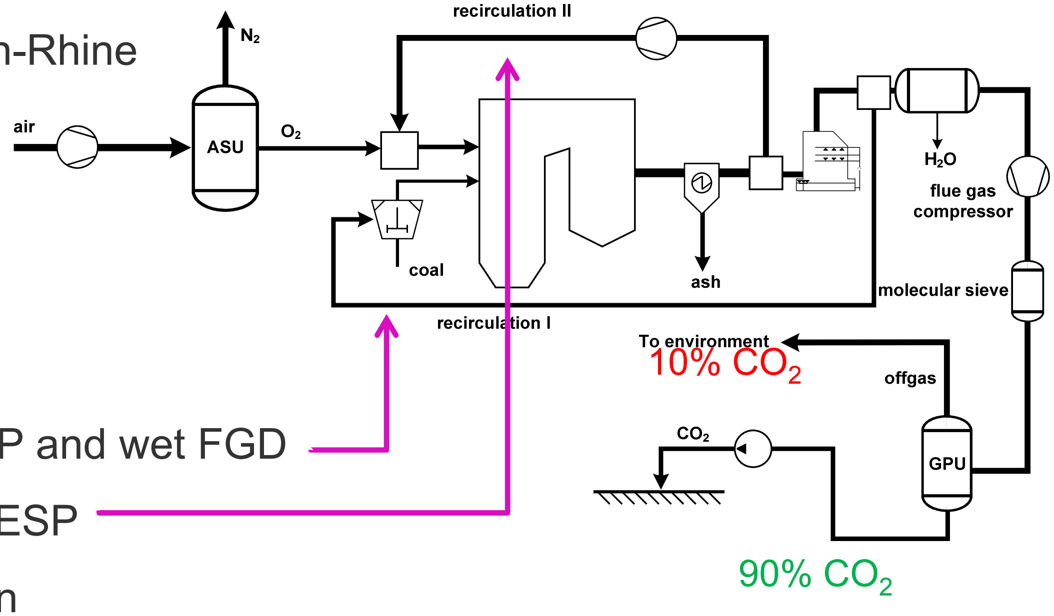
- **Reference power plant**
  - Study: reference power plant North-Rhine Westphalia (bituminous coal)
  - Air-fired: η_{net} = 45.8%
  - P_{el} = 600 MW_{gross}
- **Oxyfuel modification**
  - Treated primary recycle by hot ESP and wet FGD
  - Treated secondary recycle by hot ESP
  - Adiabatic ASU with heat integration
  - Preheated O_2: 95 vol% (dry)
  - $2\%_{(w/w)}$ air ingress
  - GPU: partial condensation (externally cooled)
  - 90% CO_2 capture rate, 10% CO_2 leakage with the offgas
  - CO_2 purity: 97 vol% (dry)
  - η_{net} = 36.9%



Process with maximised CO_2 capture rate

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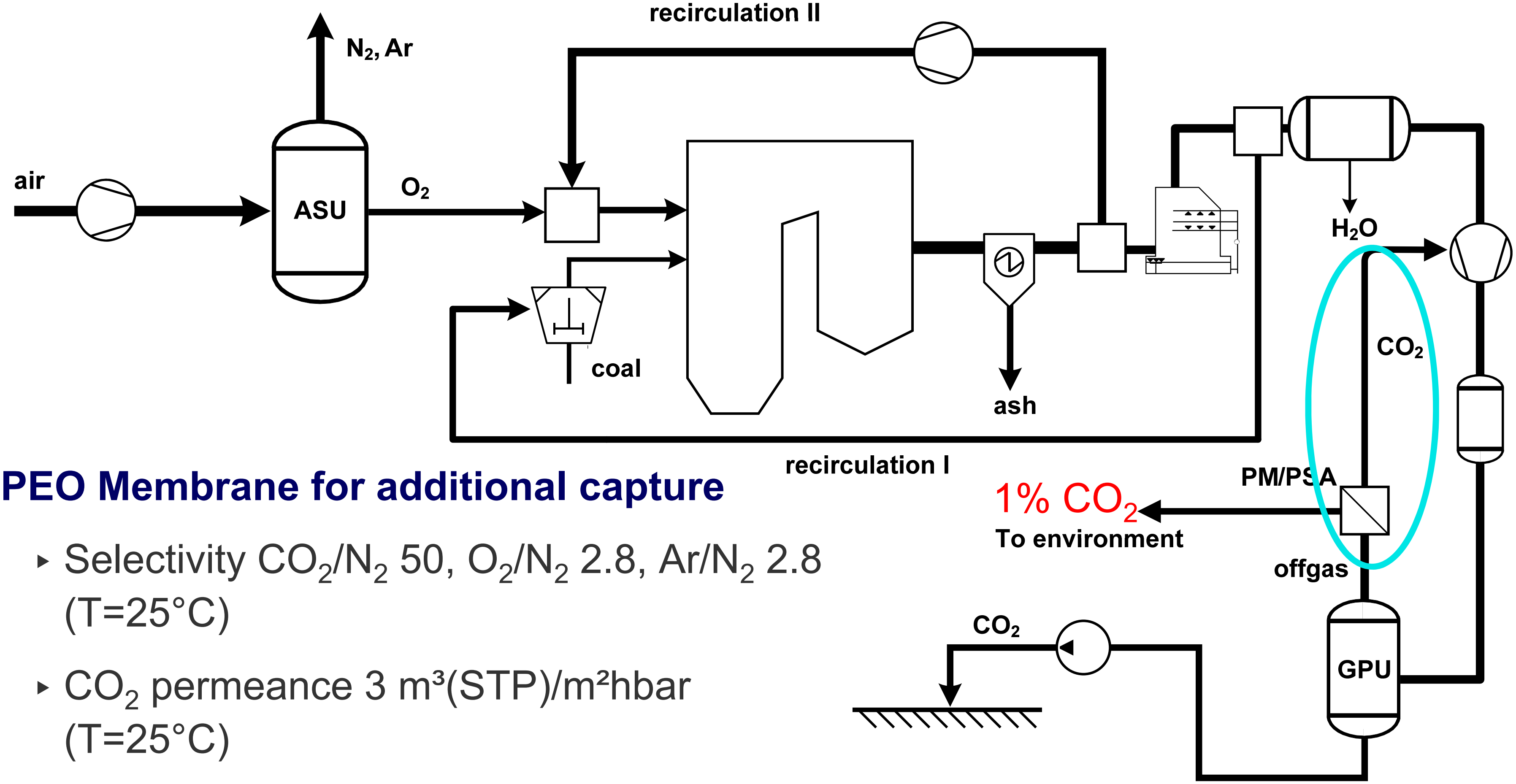


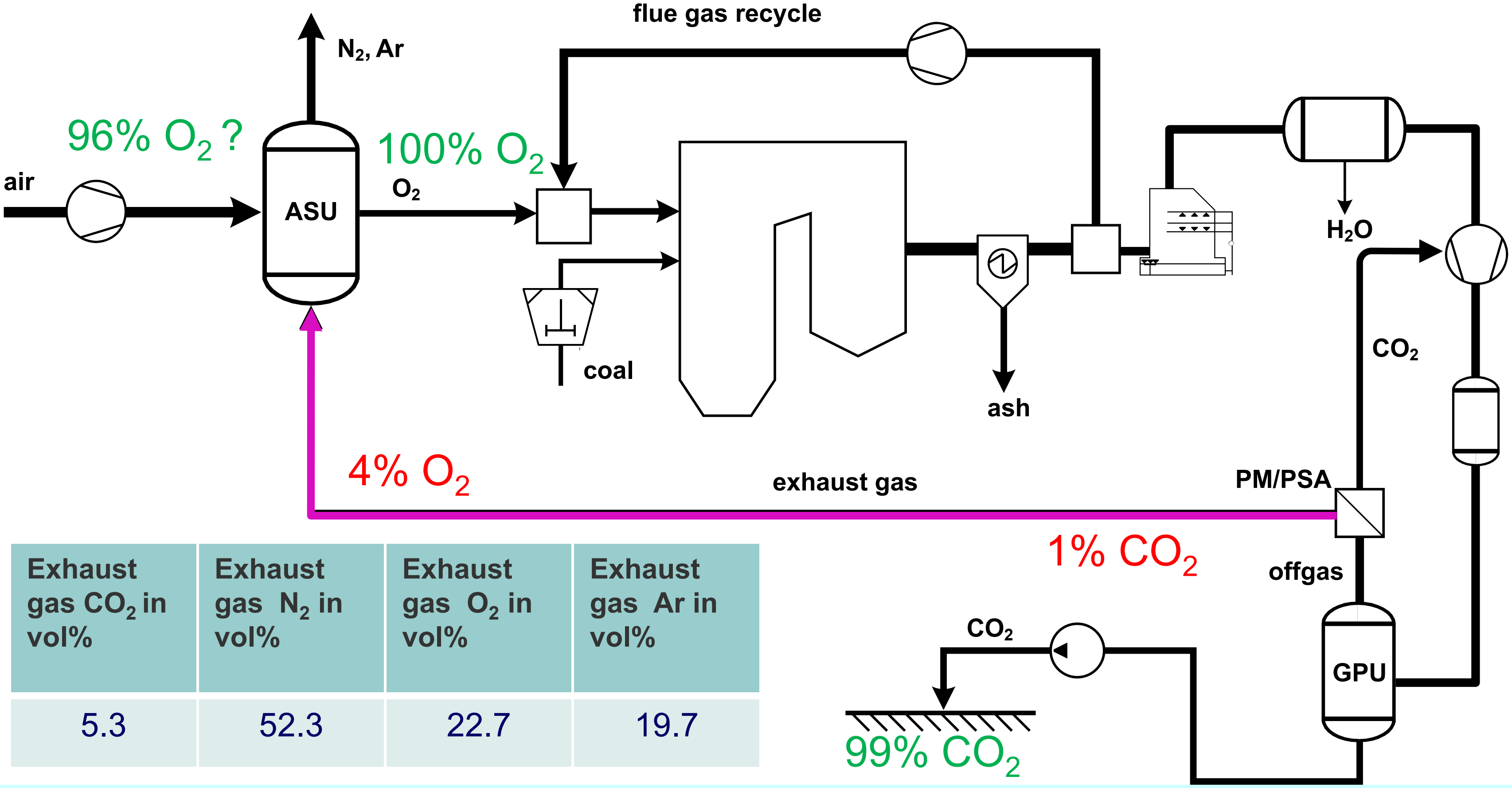
- **PEO Membrane for additional capture**
  - Selectivity CO_2/N_2 50, O_2/N_2 2.8, Ar/N_2 2.8 (T=25°C)
  - CO_2 permeance 3 m³(STP)/m²hbar (T=25°C)
- **CO_2 capture rate 99%, η_{net} = 36.4%**
- **CO_2 from PM is recycled due to low purity and pressurisation**

- **Additional capture process resolves in a net efficiency penalty of 0.5 %-pts.**
- **Exhaust gas to environment contains 4% of the oxygen supplied by the ASU**
- **Recycle to ASU can decrease its energy demand**
- **Increase of net efficiency possible**

- **Modelling of an exhaust gas recycle to the ASU**
- **Examine how much of the maximum 4% energy saving at the ASU can be realised**
- **Membrane and Adsorption not considered for separation, because of low separation selectivity of Ar/O_2**

Potential of a O_2 recycle to the ASU

- **Estimation of the potential to lower the energy demand of the ASU**
- **4% of the oxygen supplied by the ASU in the offgas**

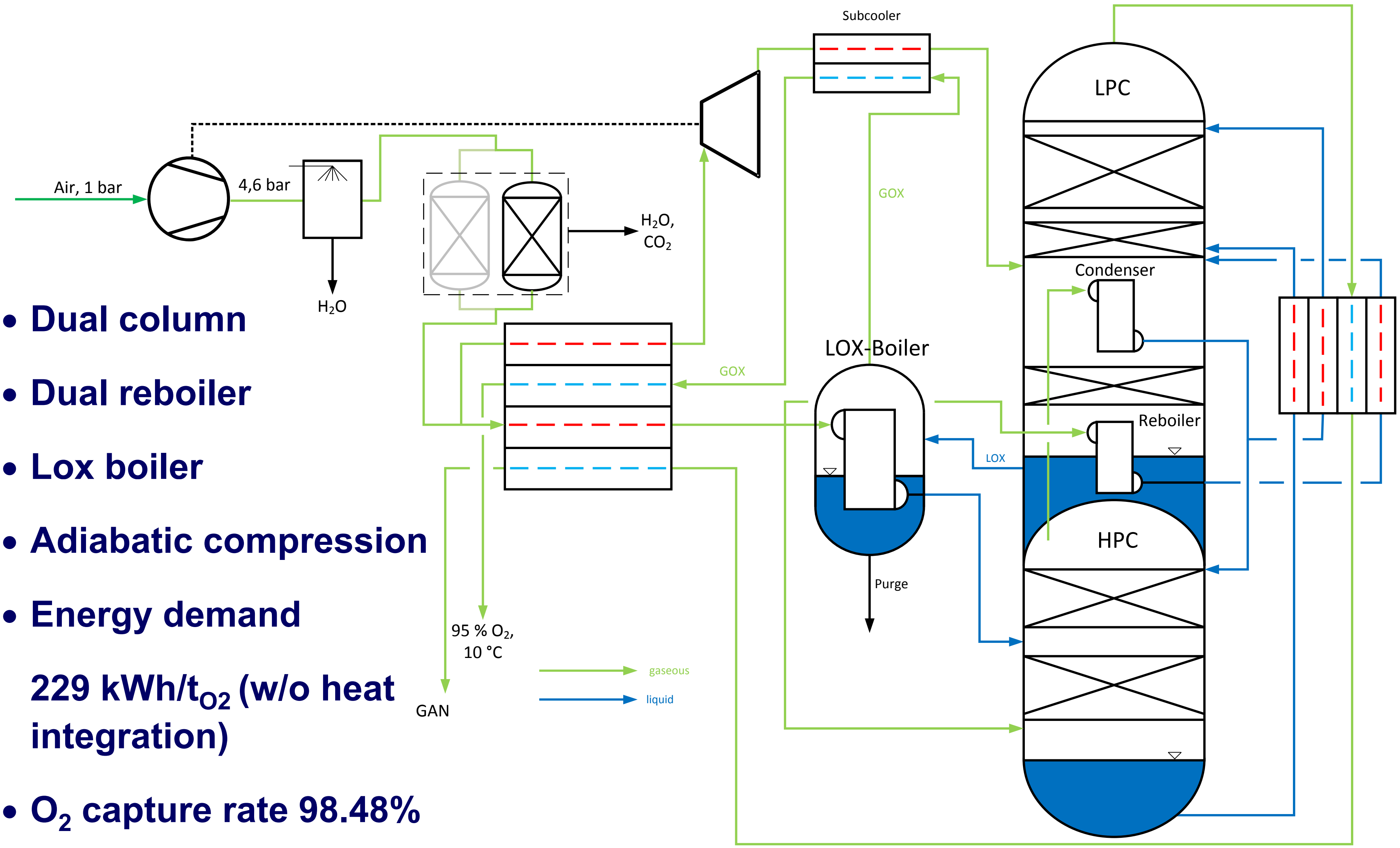


Exhaust gas CO_2 in vol%	Exhaust gas N_2 in vol%	Exhaust gas O_2 in vol%	Exhaust gas Ar in vol%
5.3	52.3	22.7	19.7

Dual column with dual reboiler and liquid oxygen boiler – basic process

- **Dual column**
- **Dual reboiler**
- **Lox boiler**
- **Adiabatic compression**
- **Energy demand**

  229 kWh/t_{O2} (w/o heat integration)
- **O_2 capture rate 98.48%**



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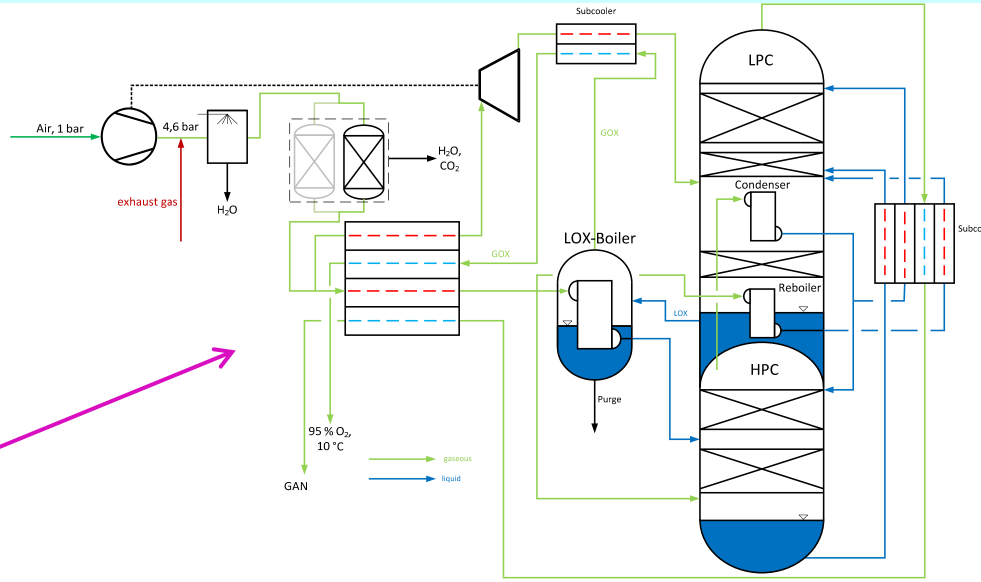
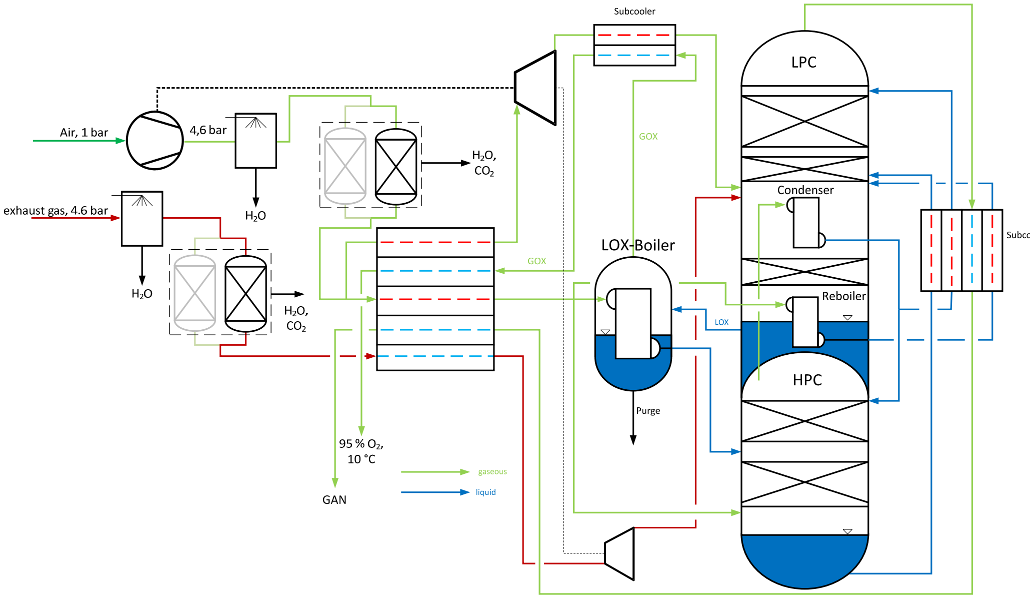
- **Recycle is on pressure (about 4.6 bar) => 2 MW higher power demand of the GPU**
- **Constant amount of O_2 and purity in product stream**
- **Scenario A with direct mixture upstream direct contact cooler**
- **Scenario B with separate feed to the cold box**





	Basic process	A (Dir. Mix with change)	B (sep. feed with change)
O_2 capture rate in %	98.48	97.9	98.27
Spec. energy demand in kWh/t_{O2} (w/o heat integration)	229	226	223
Ar in O_2 product	0.024	0.043	0.029

- **Overall process evaluation (with adiabatic compression)**
  - Benefit for the ASU results in a net efficiency penalty for the overall process for the dual column

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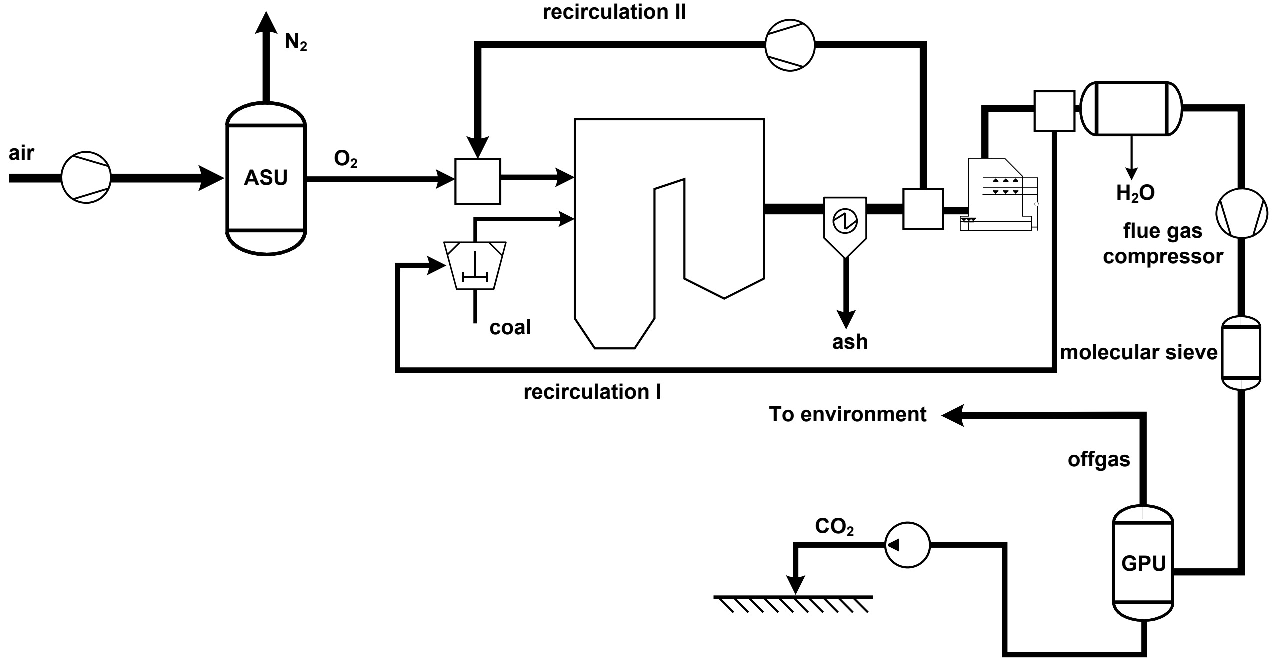
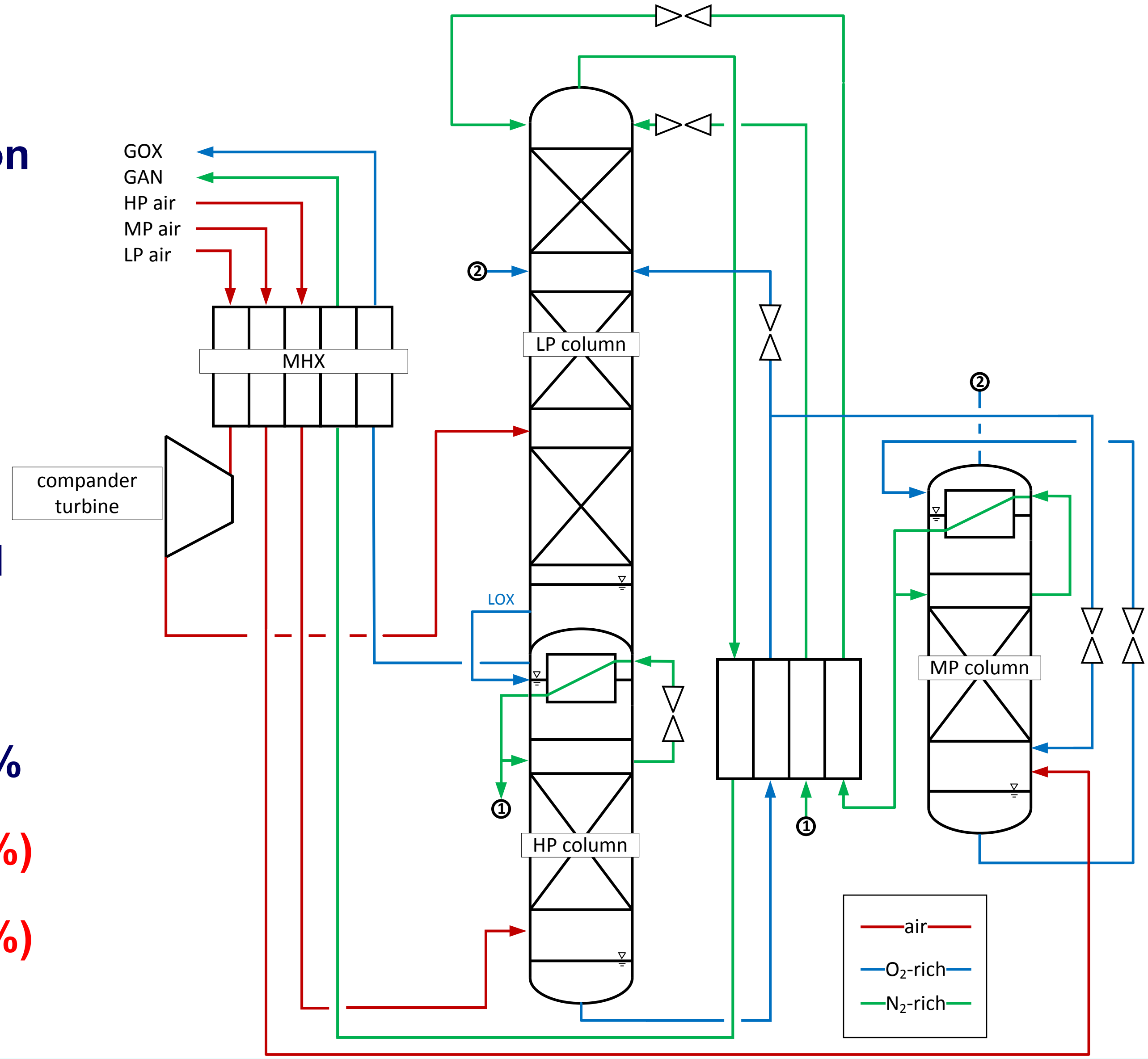
- **Integration into ASU**
  - Only small benefit for the ASU due to problems of the columns with the high amounts of Ar (increased about 70% compared to basic process)
  - The capture rate is decreased in both scenarios, because the Ar leads to an increased slip of O_2 with the N_2
- **Is there a benefit for the overall process with a triple column?**



- **Triple column**
- **Adiabatic compression**
- **Lox boiler**
- **Energy demand**

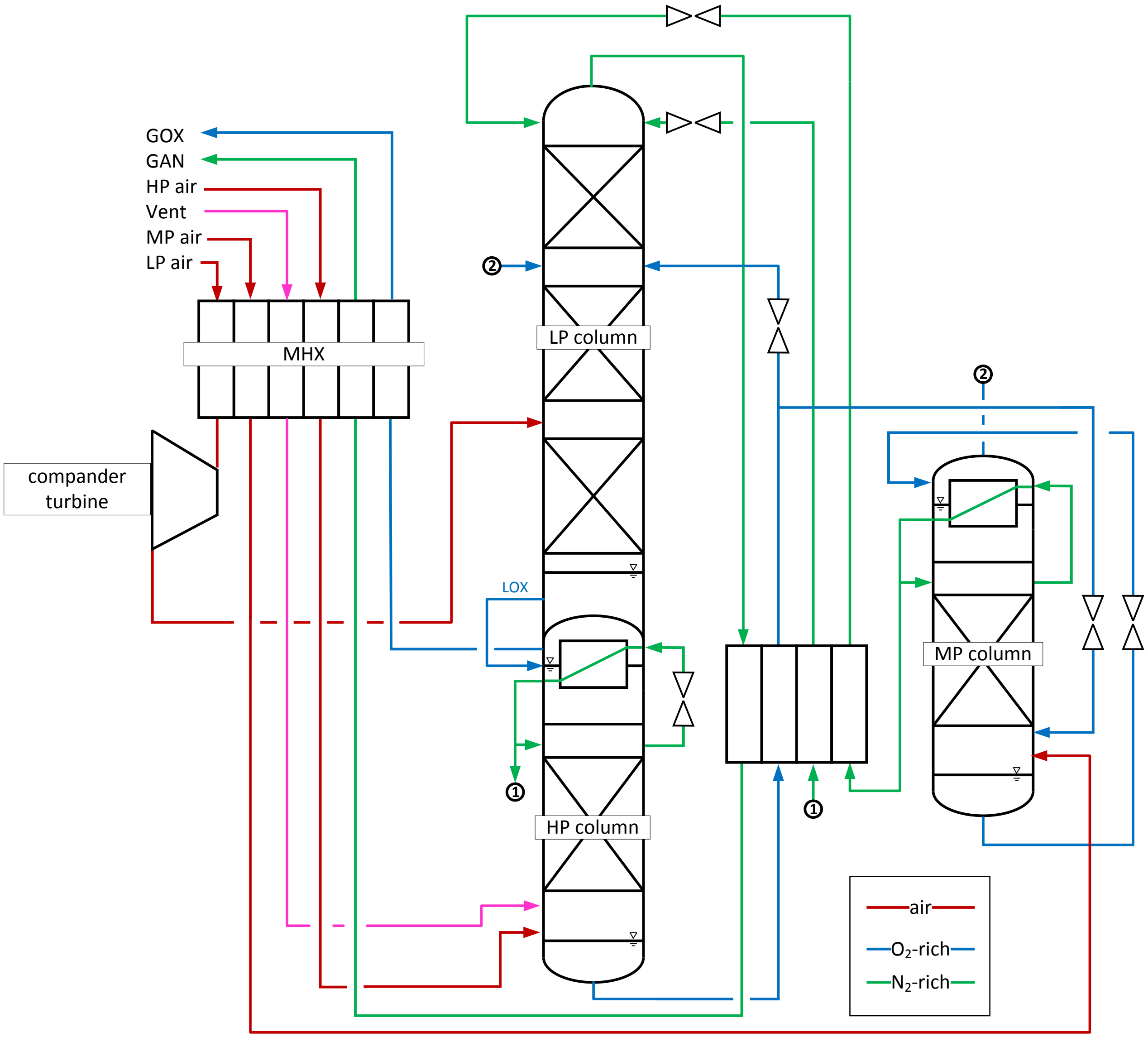
  197 kWh/t_{O2} (w/o heat integration)
- **Expander power used with generator/compander**
- **O_2 capture rate 97.85%**
- **η_{net} = 37.4% (CCR 90%)**
- **η_{net} = 36.9% (CCR 99%)**



Triple column with exhaust gas integration into the HPC

- **Energy demand**

  184 kWh/t_{O2} (w/o heat integration)
- **O_2 capture rate 97.85%**
- **Exhaust gas into HPC**
- **η_{net} = 37.15% (CCR 99%)**
- **0.25 %-pts. benefit**



Process configuration	Dual Column ASU in %	Triple column ASU in %
Basic process (CCR 90%)	36.9	37.4
Increased CCR 99%	36.4	36.9
Exhaust Gas Recycle	< 36.4	37.15

- Dual column ASU has difficulties with the effective separation of the Ar from the O_2
- For the overall process the results show no benefit for a dual column ASU with an exhaust gas recycle
- The triple column benefits from the exhaust gas recycle and can lessen the efficiency decrease of an increased capture rate to 0.25 %-pts.

- Economical evaluation of the offgas treatment with PM and PSA

Acknowlegdements

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