**Institute of Energy Systems**

Prof. Dr.-Ing. Alfons Kather

Christian Hermsdorf
Mathias Klostermann
Karl Mieske

**Institute of Thermal and Separation Processes**

Prof. Dr.-Ing. Rudolf Eggers

Daniel Köpke

Technische Universität Hamburg-Harburg

# Oxyfuel Process for Hard Coal with CO2-Capture

## Current Research at TUHH

**Young Researchers Meeting,**
**December 8th, 2006, Hamburg**

# Current Research Projects at the TUHH

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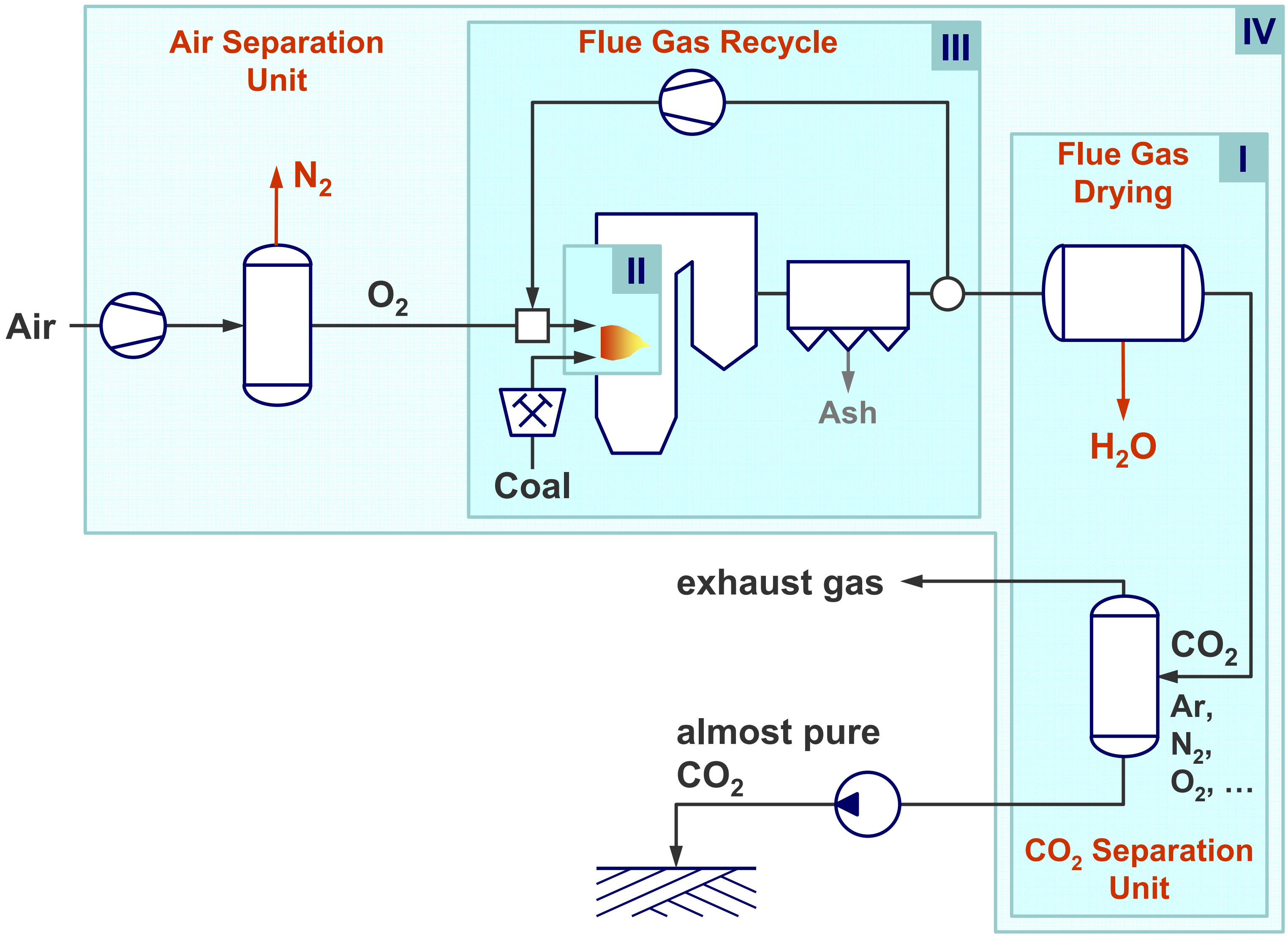
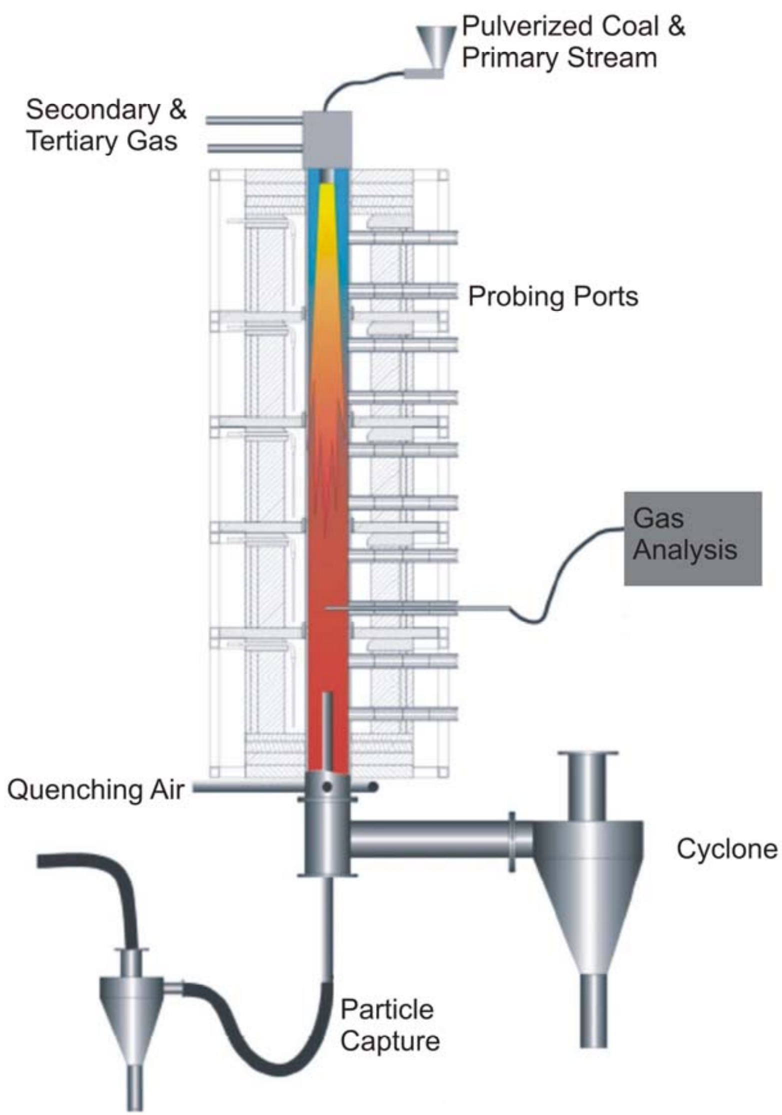


# Entrained Flow Reactor






**Combustion capacity: 20 kW**

**Heated ceramic tube:**
- ∅150 mm, 2 m length,
- 5 independent segments,
- 900 – 1600 °C

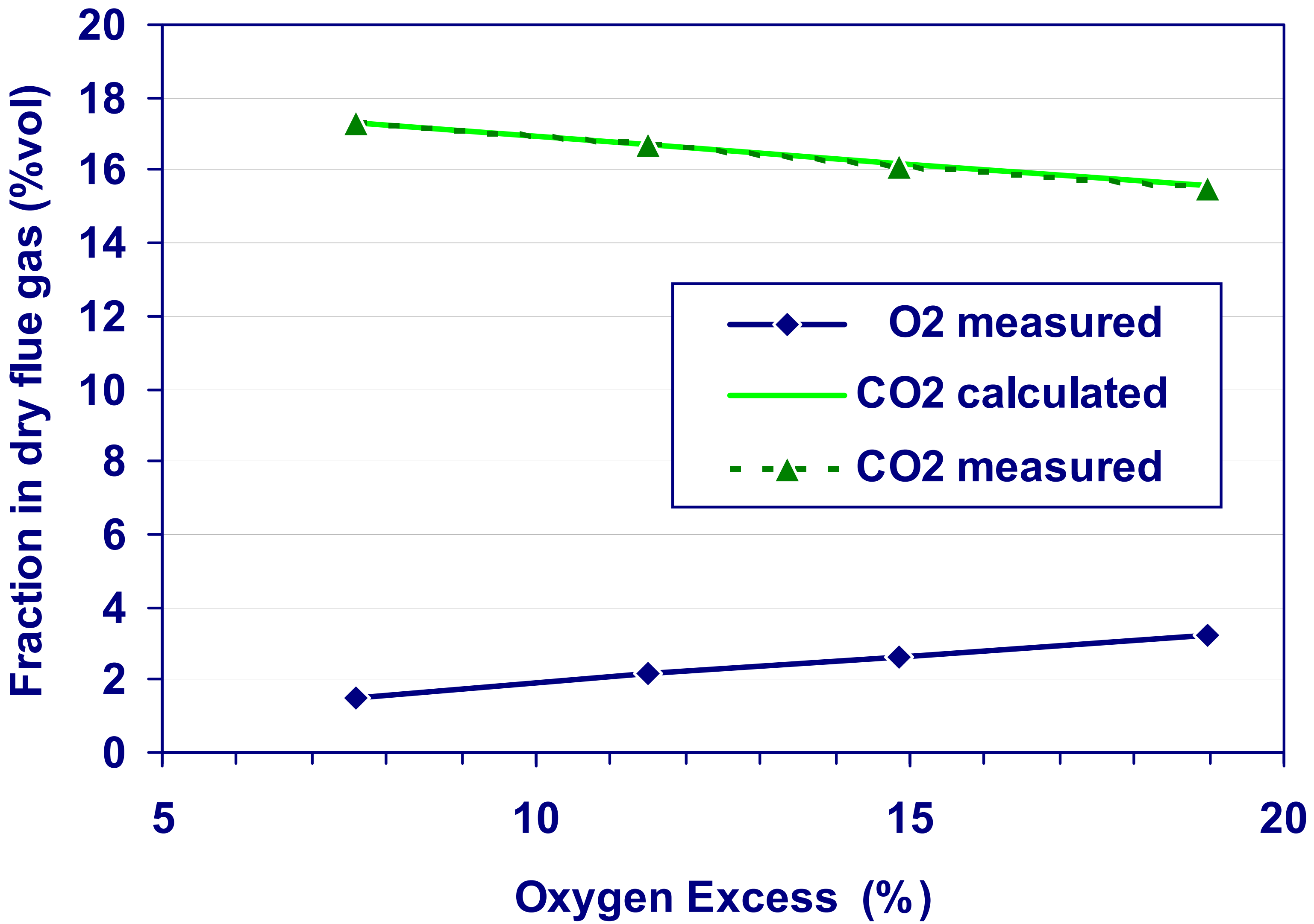
**Artificial combustion atmospheres by mixing $O_2$, $CO_2$, $N_2$, NO, $SO_2$, steam, and air**
- ➡ constant combustion conditions

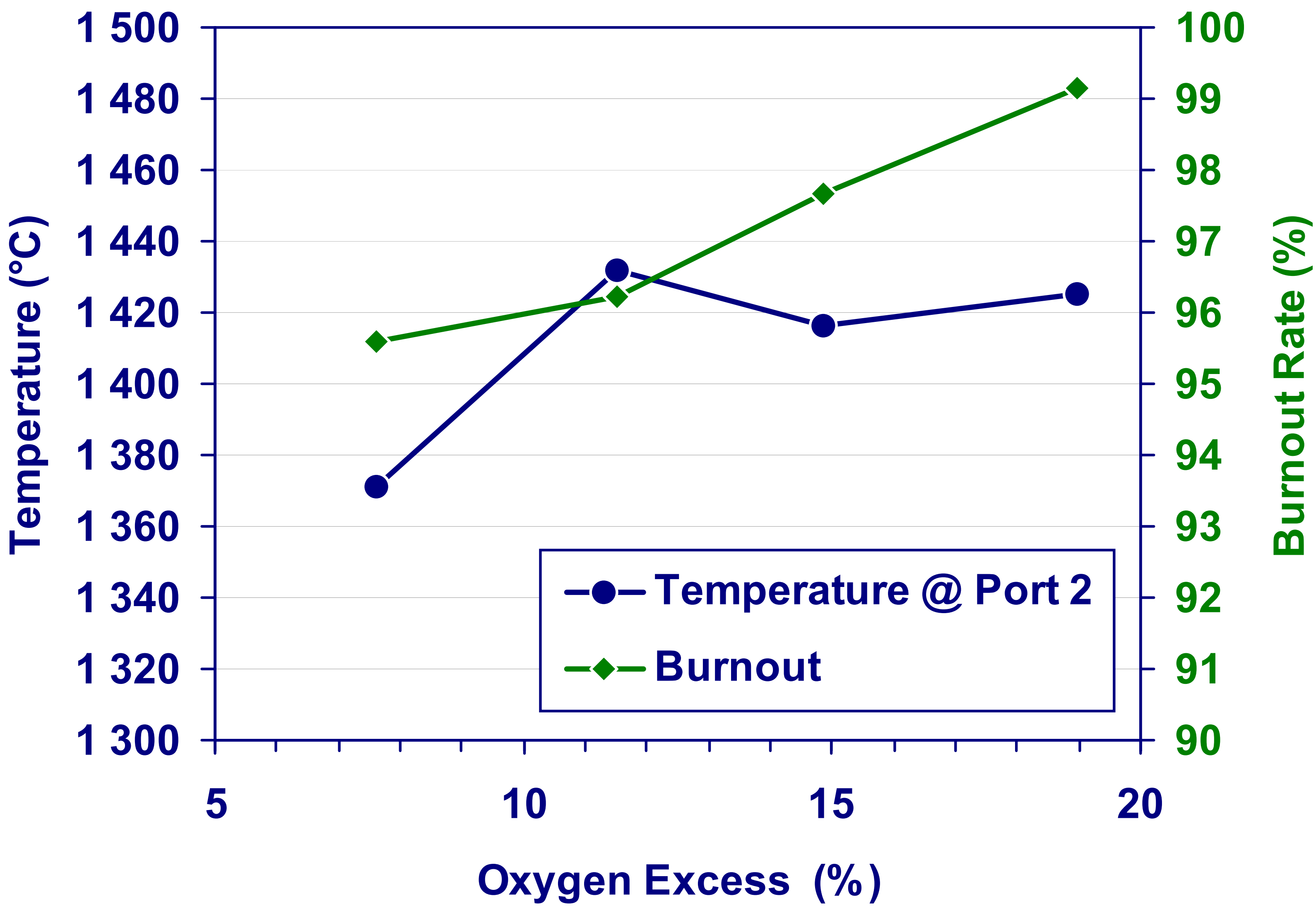
**Primary, secondary, tertiary stream and possibility of feed gas staging**

**Measurement of NO, $NO_2$, CO, $CO_2$, $O_2$, $SO_2$, and gas temperature**

# Combustion of Indonesian Hard-Coal in Air

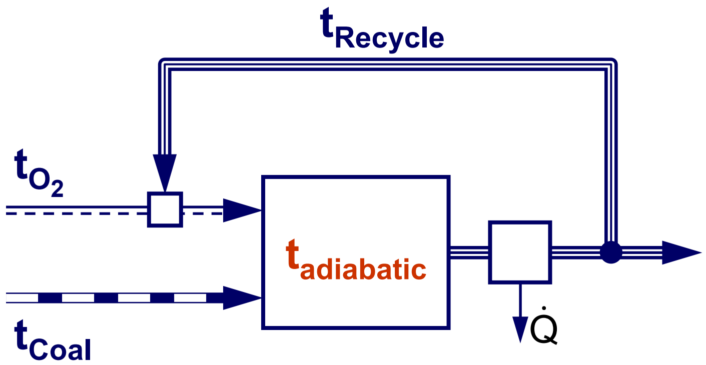





1 500
1 480
1 460
1 440
1 420
1 400
1 380
1 360
1 340
1 320
1 300
Temperature (°C)
100
99
98
97
96
95
94
93
92
91
90
Burnout Rate (%)
5
10
15
20
Oxygen Excess (%)
Temperature @ Port 2
Burnout

# Factors influencing the Recycle Requirement






- **Condition:**

  $t_{adiabatic\ w/\ Air} = t_{adiabatic\ w/\ O_2+Recycle}$

- **Underlying assumptions:**

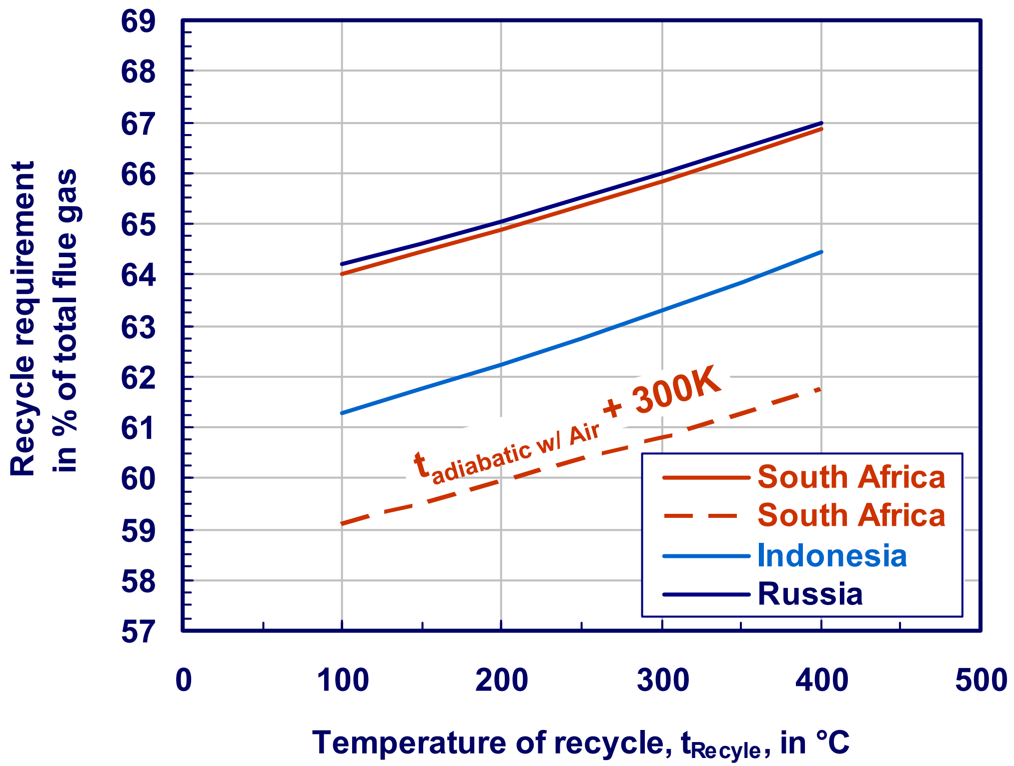
  $t_{Air}$ = 320 °C

  $t_{O_2}$ = 20 °C

  $t_{Coal}$ = 40 °C

  $O_2$-excess: 15 %

  $O_2$-purity: 98 %




| | Composition (in wt%) | | | | | | | NCV | $t_{ad,Air}$ |
|---|---|---|---|---|---|---|---|---|---|
| Coal | C | H | O | S | N | Ash | $H_2O$ | MJ/kg | °C |
| South Africa | 65,93 | 3,63 | 7,25 | 0,61 | 1,58 | 13,60 | 7,40 | 25,40 | 2126 |
| Indonesia | 58,70 | 4,43 | 8,82 | 1,00 | 1,05 | 5,00 | 21,0 | 22,69 | 2008 |
| Russia | 70,09 | 3,70 | 7,37 | 0,30 | 1,23 | 9,81 | 7,50 | 27,20 | 2160 |

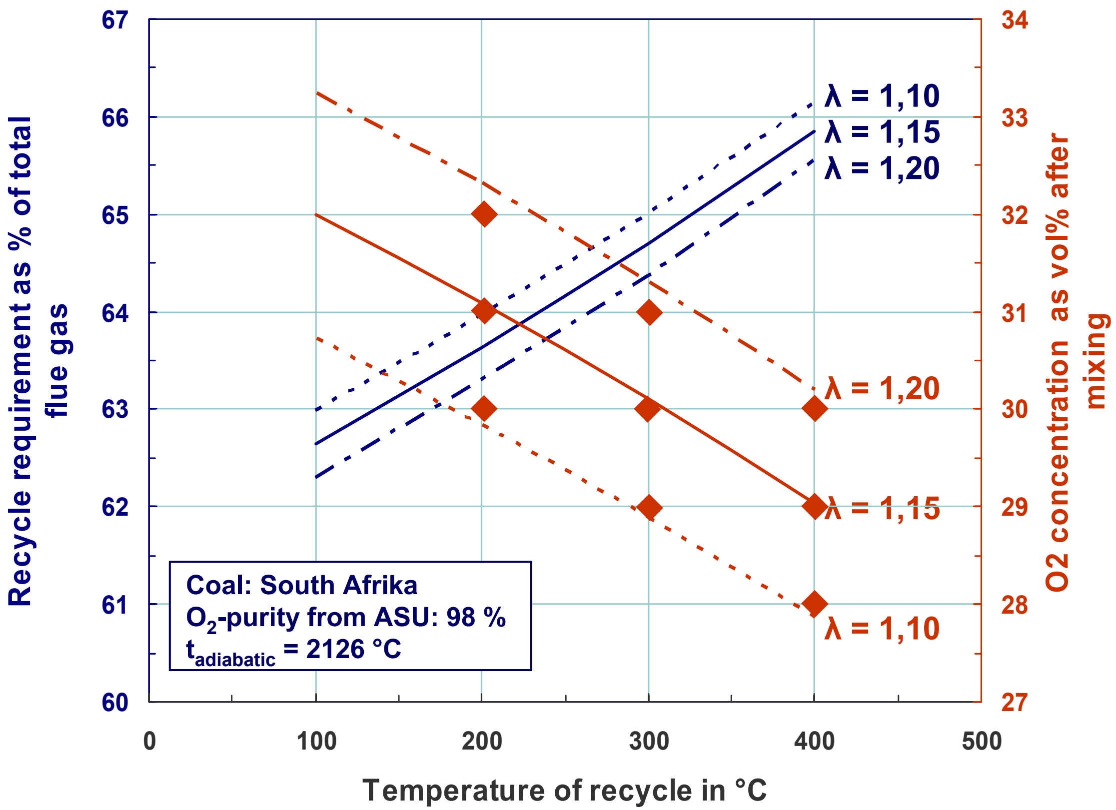
# Oxygen Concentration in the Combustion Atmosphere

- **First approach:** Oxygen and recycled flue gas are mixed completely before combustion
- **Feed-gas composition:** is calculated assuming complete combustion

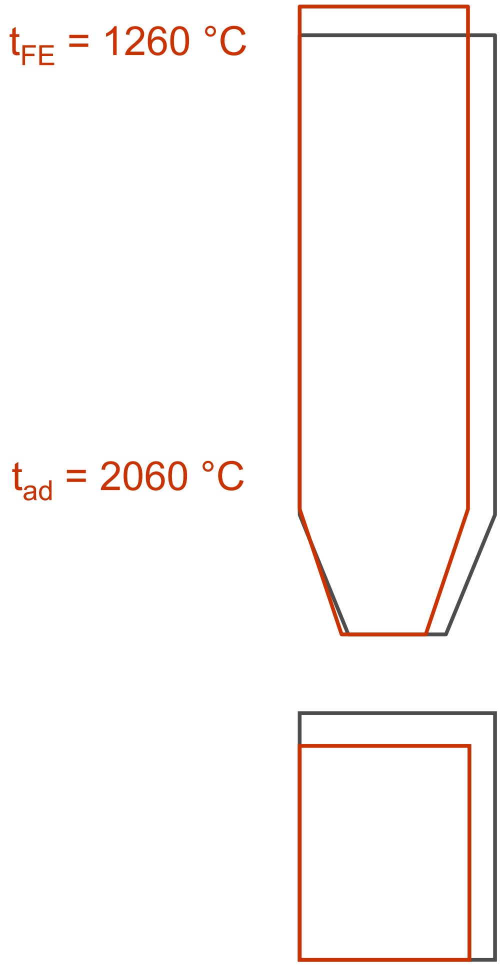
**To reach an equal adiabatic temperature the oxygen concentration**

- rises by reducing the recycle,
- is always above 21 vol%.

- **First combustion experiments (◆)**



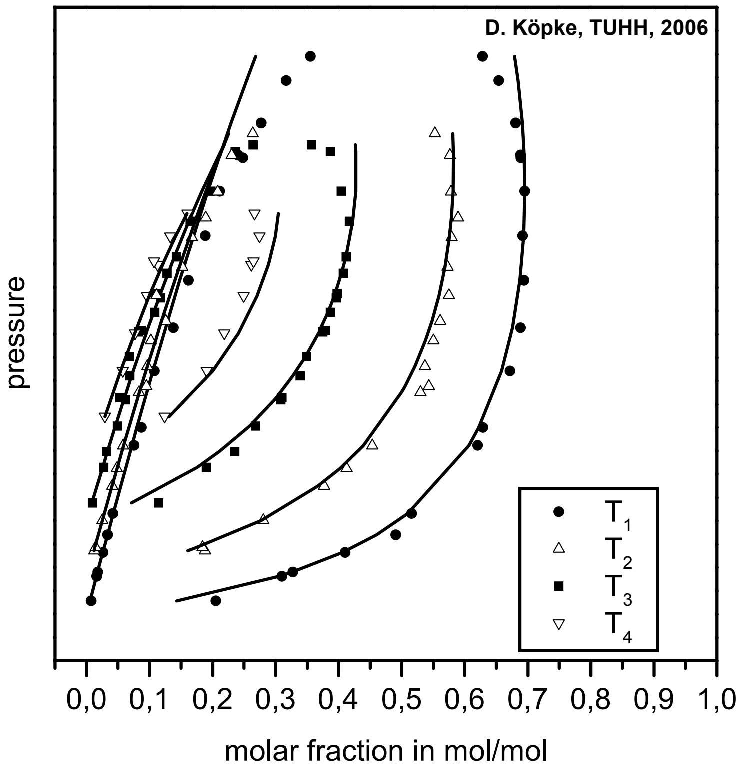
## Comparison of the furnace dimensions of a conventional boiler with an Oxyfuel boiler of equal thermal power

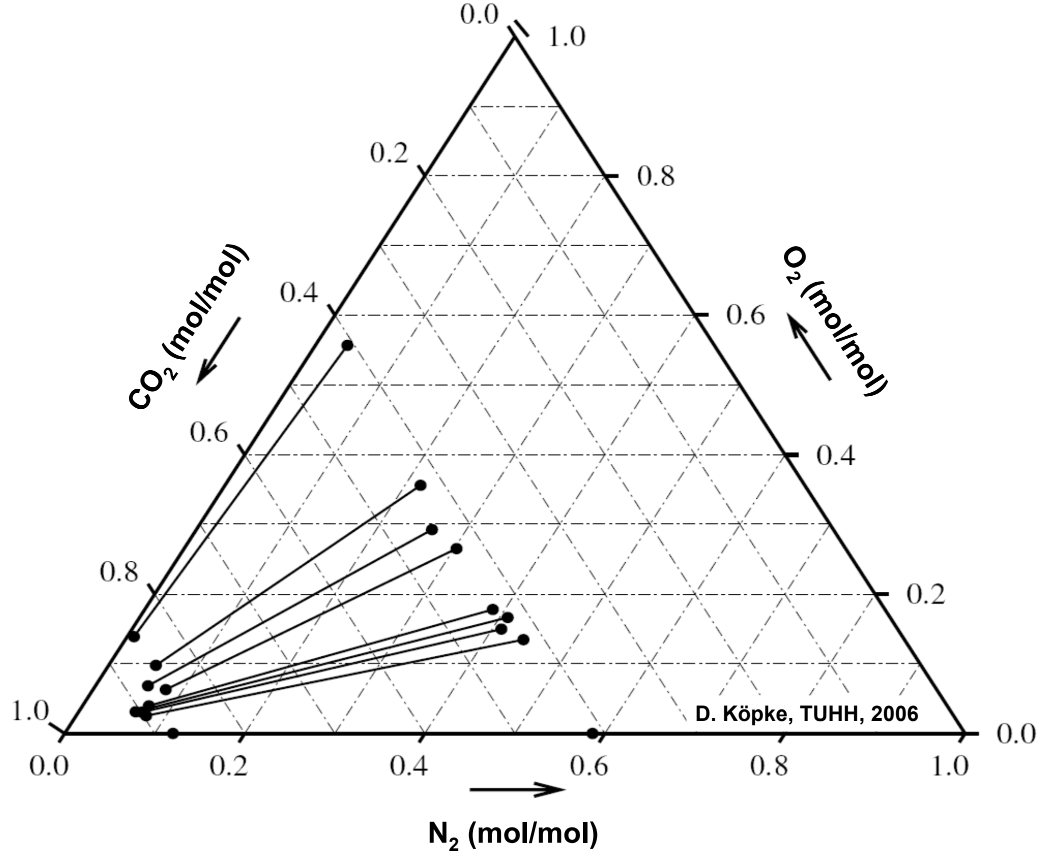



- ≈ 15 % lower flue gas mass stream
- ≈ 22 % higher density of the flue gas
  - ➡ ≈ 30 % smaller cross section of furnace
  - ➡ ≈ 17 % smaller circumference of furnace
  - ➡ furnace ≈ 17 % higher with unchanged heat transfer

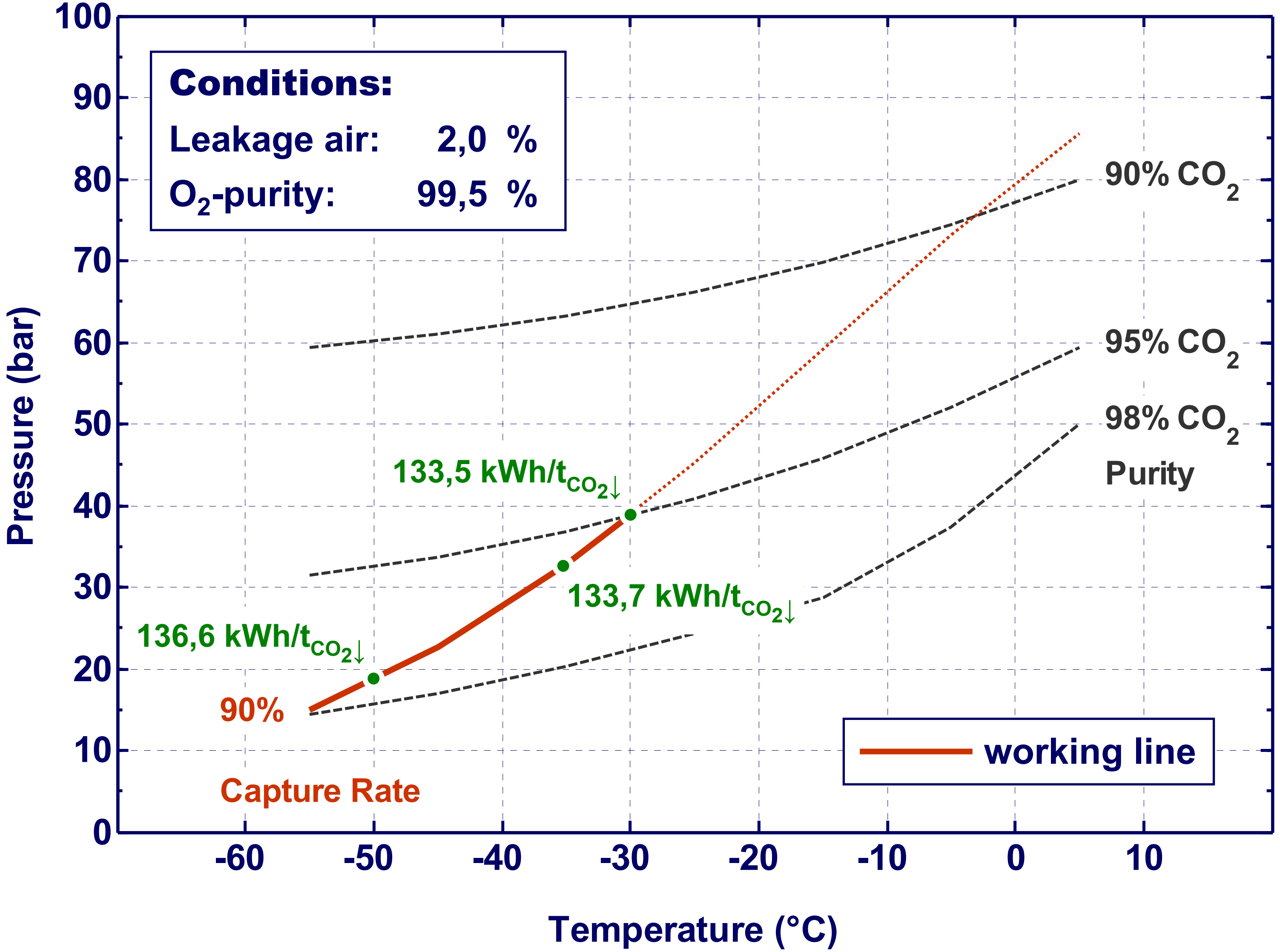
- Improved radiant heat transfer ($H_2O$, $CO_2$, dust) leads to ≈ 5 % higher furnace

- **Binary phase equilibria measurements**
- **Multi component phase equilibria measurement**



# p-T-diagram for single-stage cryogenic $CO_2$-liquefaction



# Flue Gas Treatment and $CO_2$-Purity

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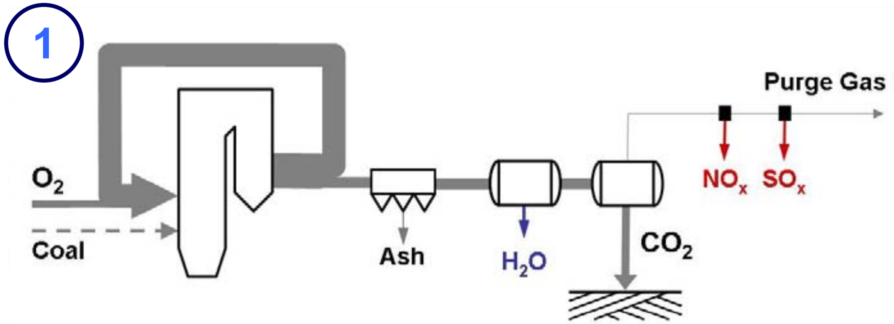
1

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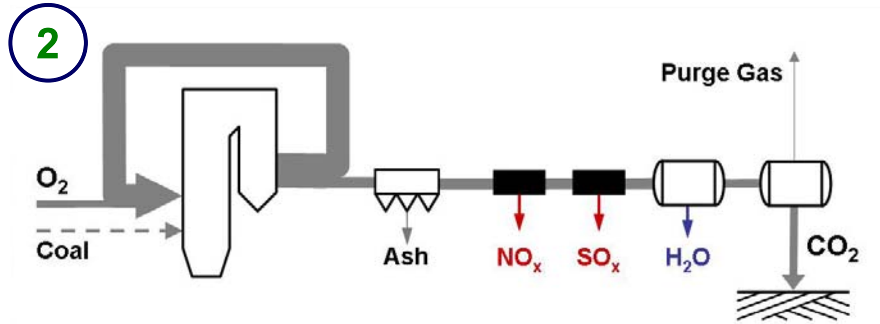
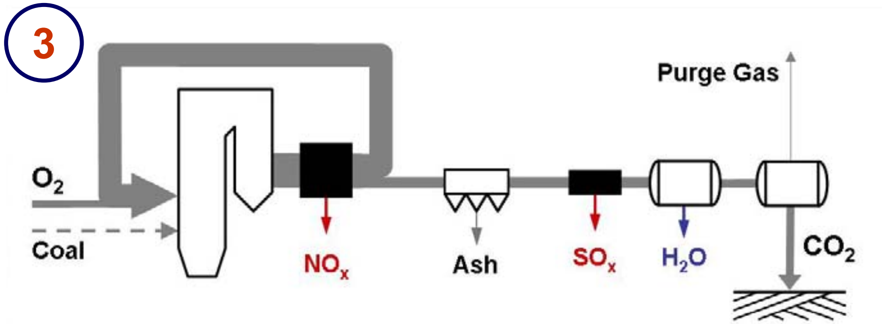



**Basic Conditions:**
**Leakage air: 1.0 %**
**$O_2$-purity: 99.5 %**

3

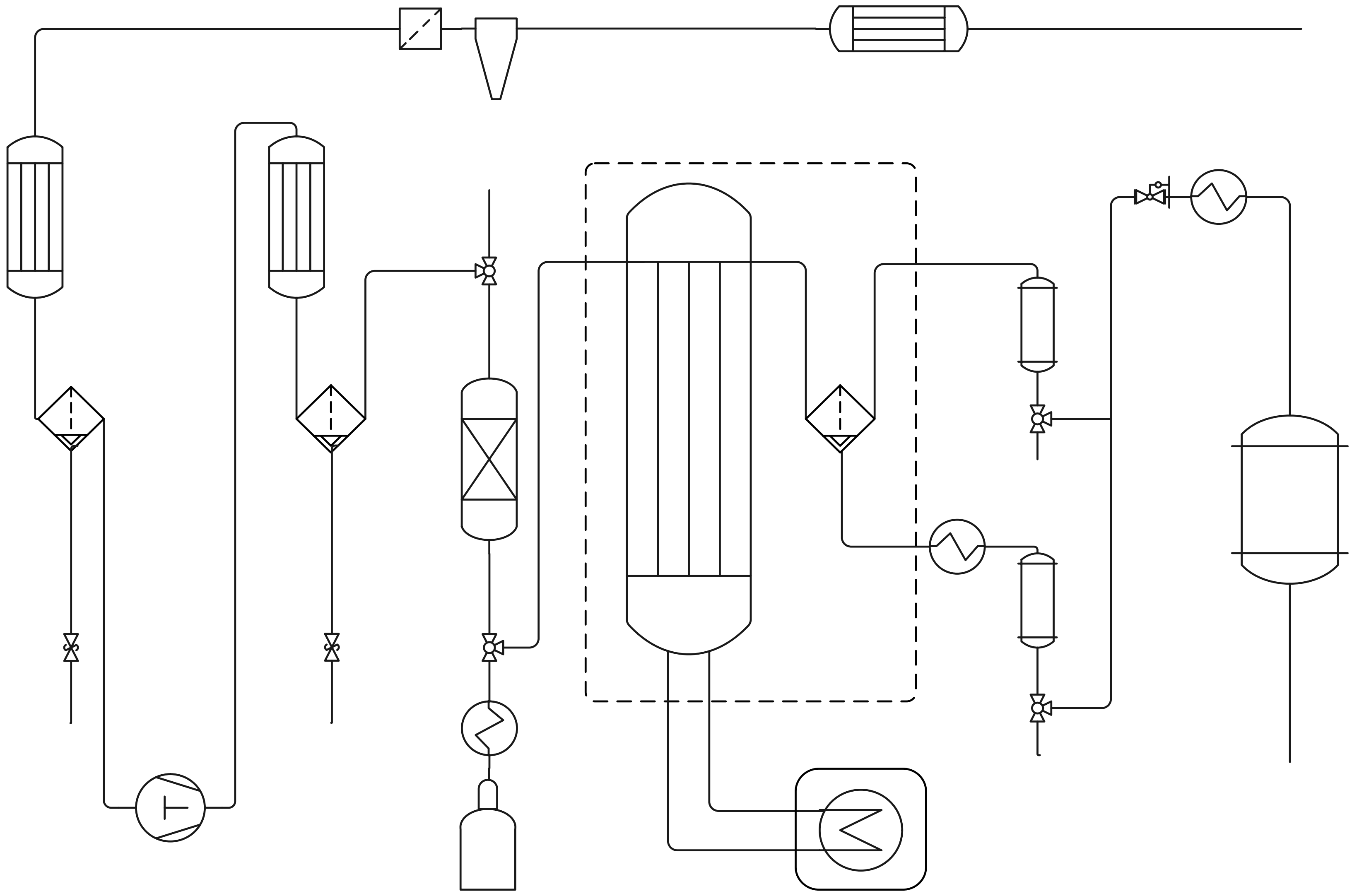



**Purity of liquefied $CO_2$** (in mol-%)

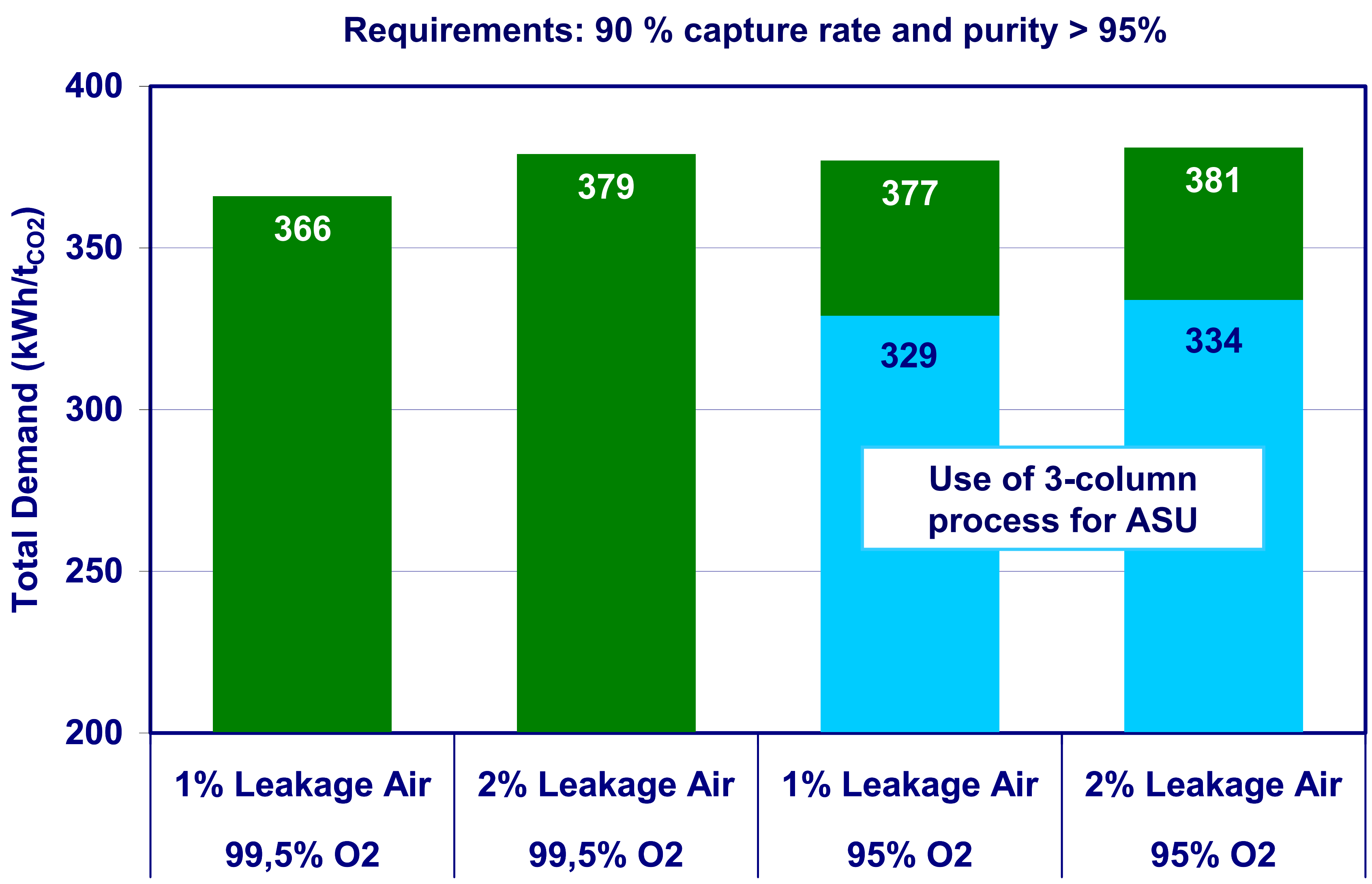
| | $CO_2$ | $N_2$ | Ar | $O_2$ | $SO_2$ | $NO_x$ |
|---|---|---|---|---|---|---|
| 1 | 98.4 | 0.6 | 0.2 | ≈ 0.4 | ≈ 0.4 | ≈ 470 ppm |
| 2 | 98.8 | 0.6 | 0.2 | ≈ 0.4 | ≈ 56 ppm | ≈ 47 ppm |
| 3 | 98.8 | 0.6 | 0.2 | ≈ 0.5 | ≈ 56 ppm | ≈ 22 ppm |

# Flue Gas Liquefaction Plant





# Additional Energy Demand



# Comparison of Different Processes
## (1% Leakage, Capture Rate 90%, Purity > 98,5%)

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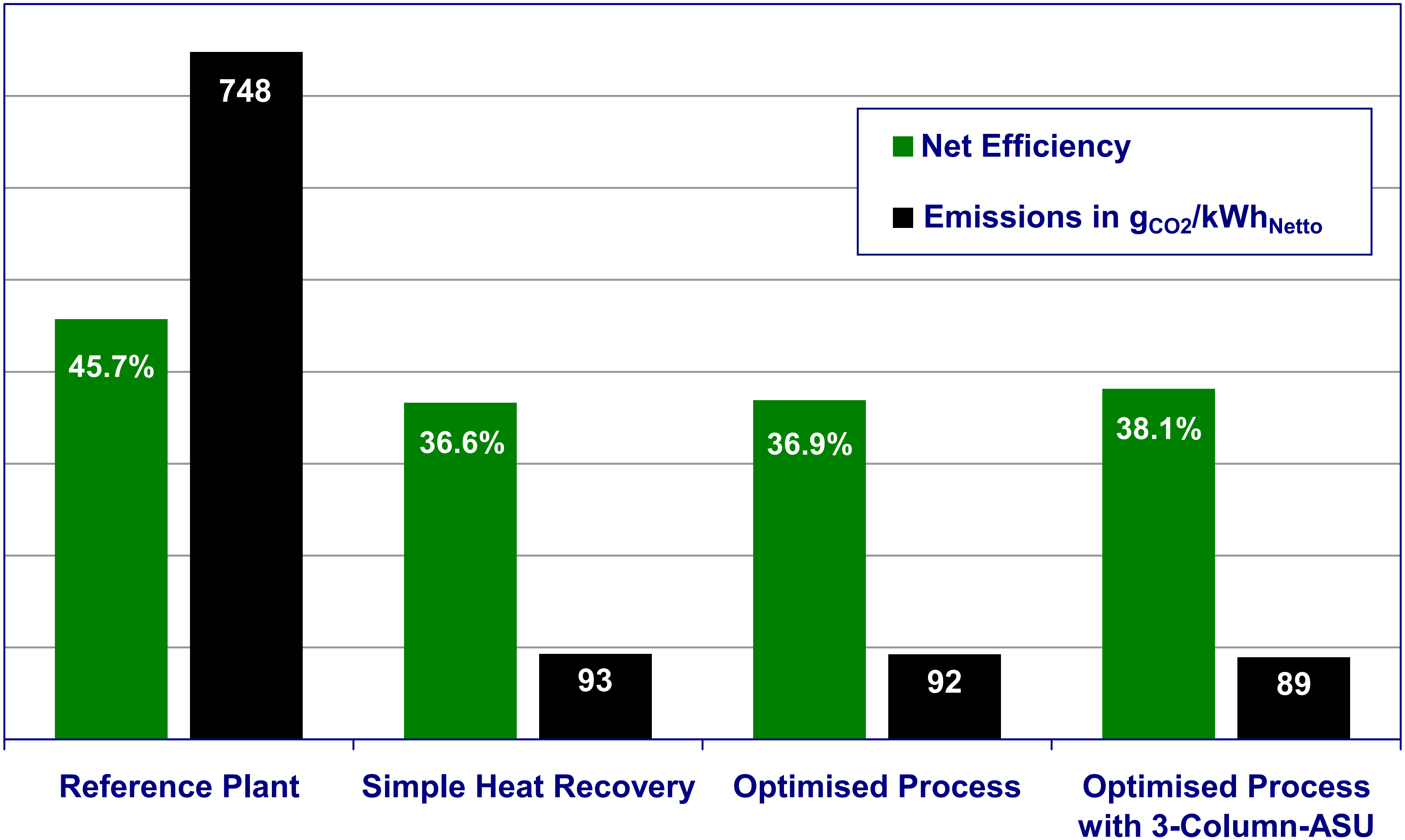

# Efficiency of an Oxyfuel Power Plant

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- **Underlying reference technology**
  - Reference power plant North-Rhine Westphalia: $\eta$ = 45.7 % (net)
    power output: 556 MW (net), 600 MW (gross)

- **Key power consumers (based on 600 MW gross power output)**
  - Air Separation Unit:
    ≈ 90 MW to attain 99.5 vol% oxygen purity
    ≈ 70 MW at the expense of oxygen purity (95 %) using a new, not yet realized separation technology (3-column-process)

  - $CO_2$ Separation Unit (90 % separation, 1 % leakage air):
    ≈ 47 MW possibly lower due to optimization

- **Estimated efficiency loss:** **$\Delta\eta$ = 8 … 10 … 11.5 % abs.**

# Thank You!