

# CO<sub>2</sub> Compression

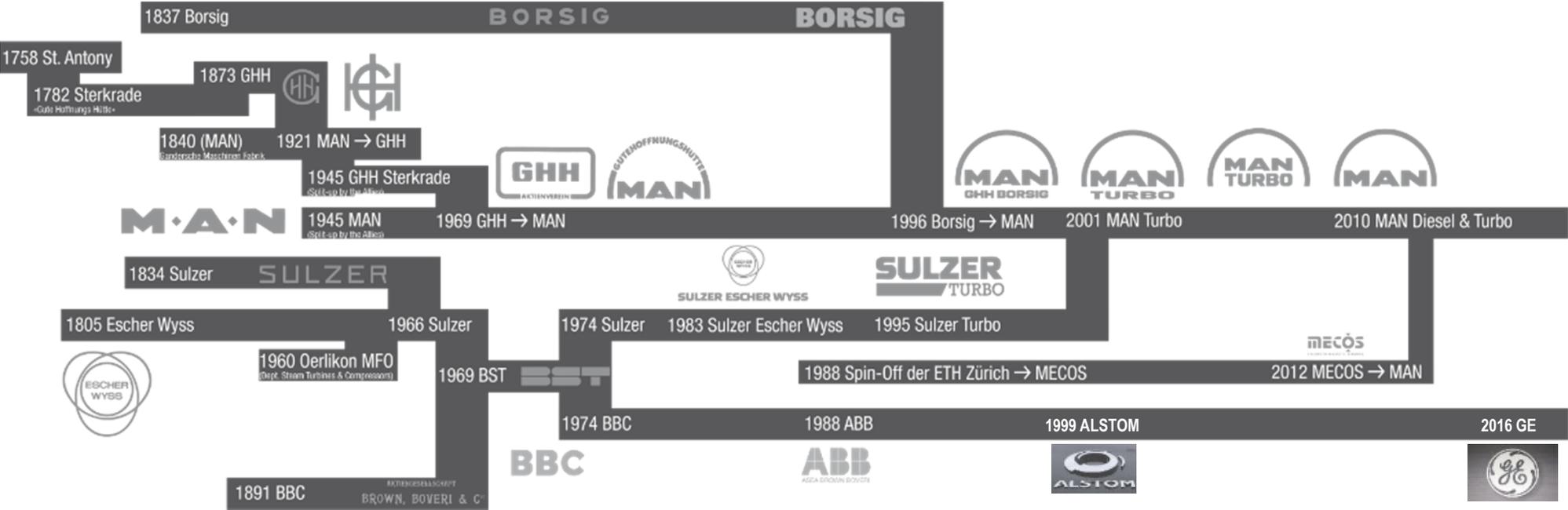
# AGENDA



- 1 Brief Company overview
- 2 CO2 Applications overview
- 3 CO2 Compression Concept
- 4 Product / Solutions development
- 5 Selected References

# Company History

The Future Needs the Past



# MAN Energy Solutions

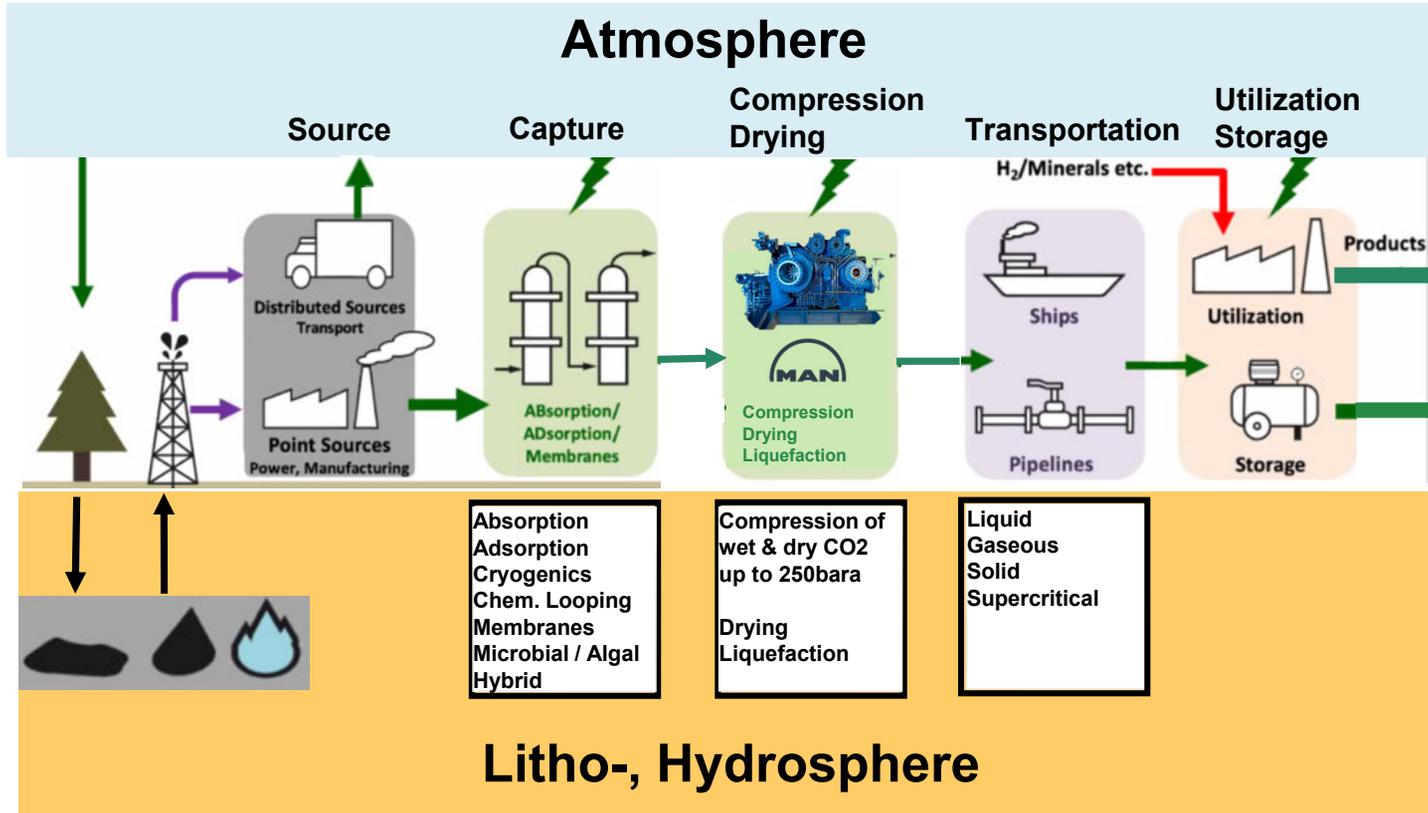
Facilities - CCUS



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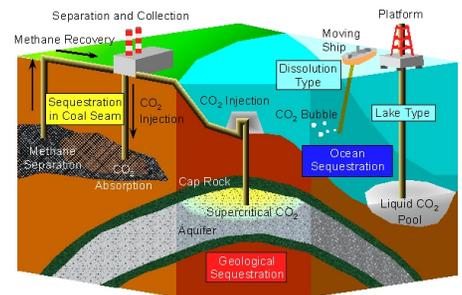


**10 – 30% Utilization**

- Food
- Greenhouse
- Chemicals
- Mineralization
- Fertilizer
- Synthetics
- Fuels
- PTX
- Methanation

**70 – 90% Storage**

Overview of CO<sub>2</sub> Sequestration Technology



# AGENDA

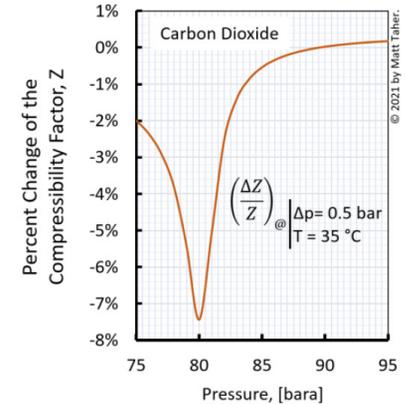
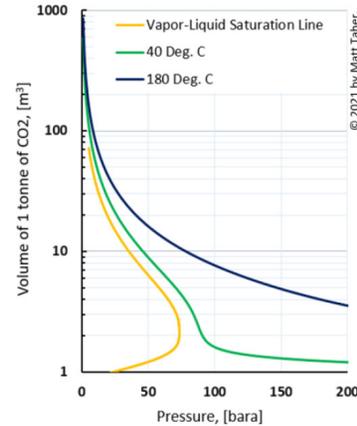


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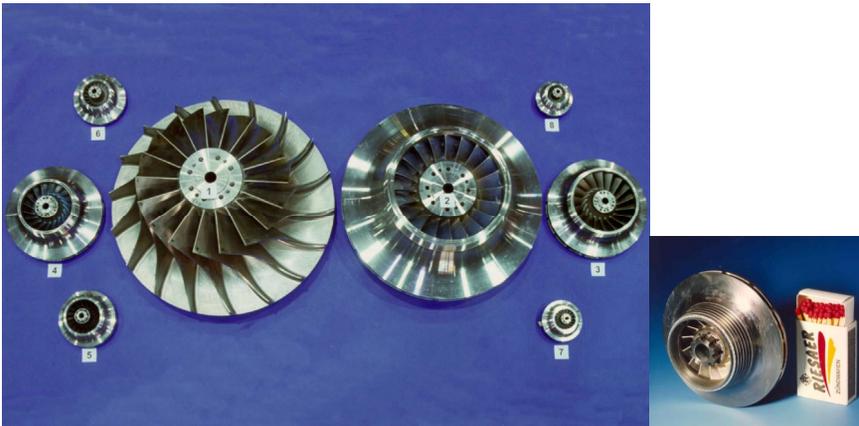
# CCS / CCUS

## CO2 properties

- Molar mass CO2 = 44 g/mol  
(Air = 29 g/mol)
- CO2 has very high compressibility
- Research Facility Berlin, Germany
  - Thermodynamic (J-T, Z, Q)
  - Mechanical (seals, bearings, gears)

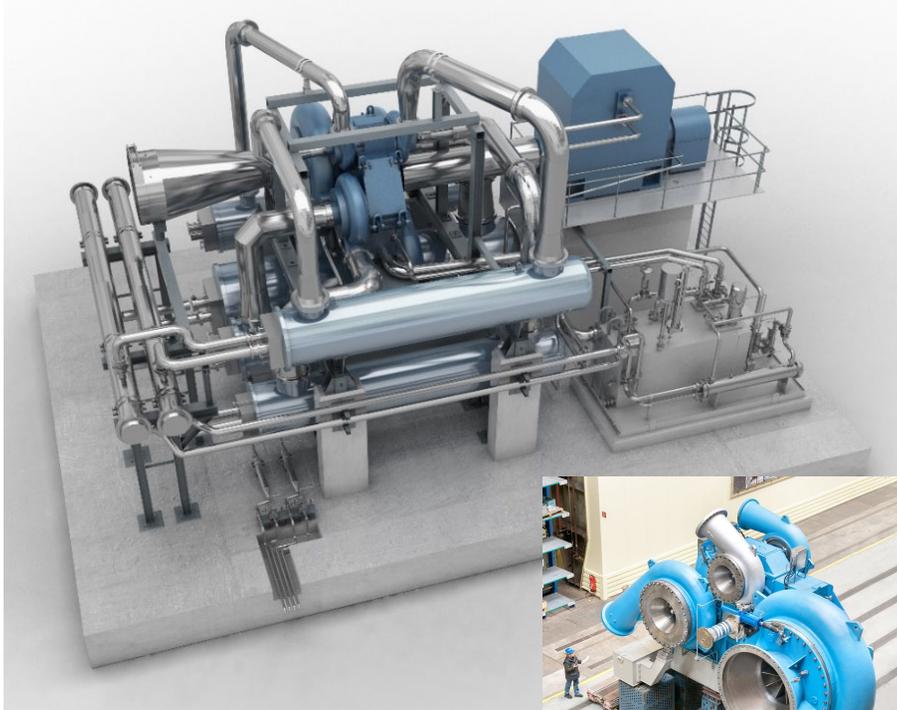


Source: Matt Taher (Bechtel Energy), "Carbon Capture: CO2 Compression Challenges and Design Options", ASME Paper # GT2022-82209



# Integrally Geared Compressor RG

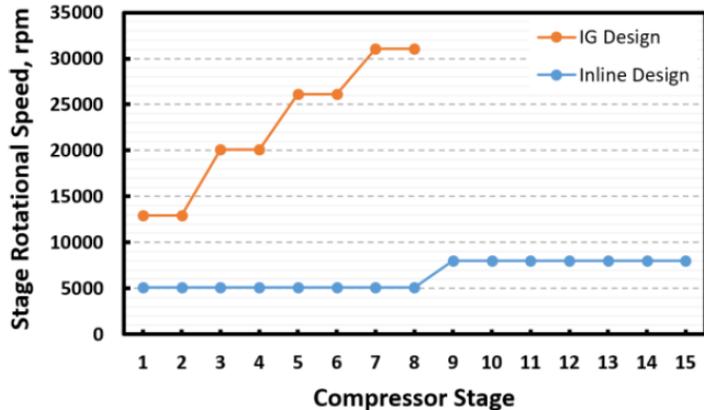
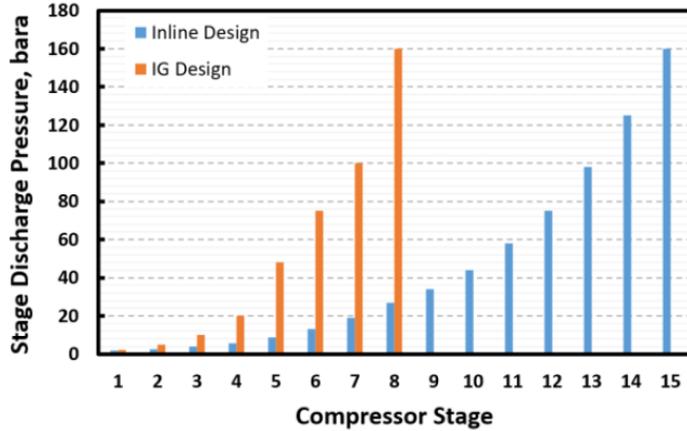
## Arrangement Overview



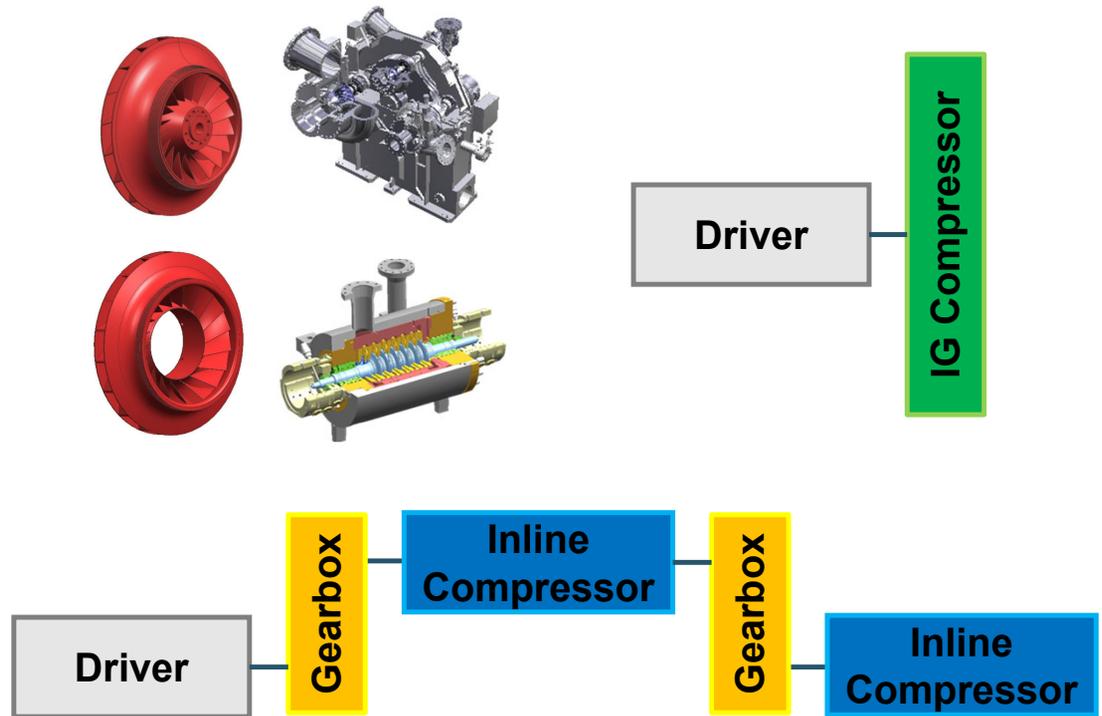
# CCS / CCU – Inline & integrally geared compression



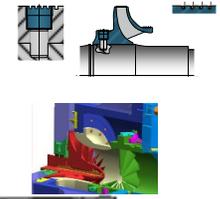
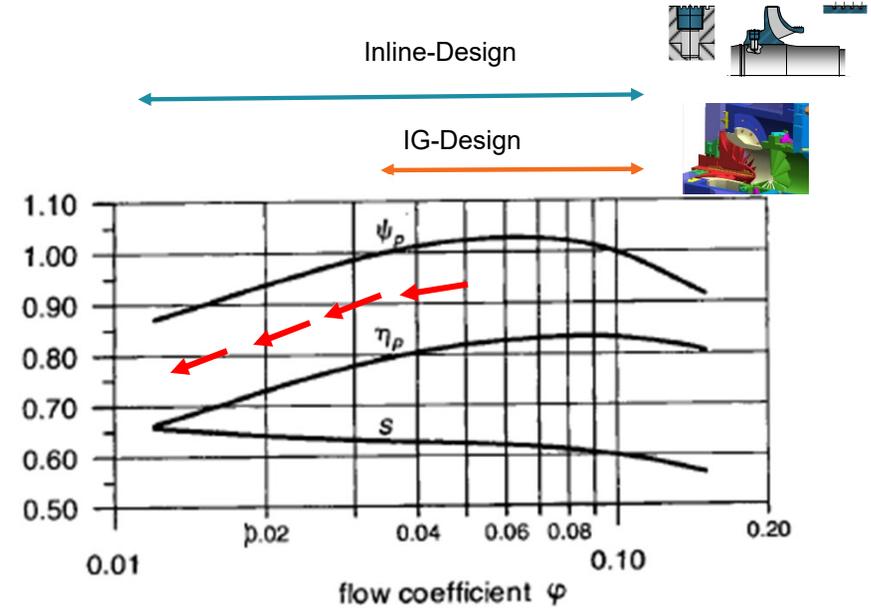
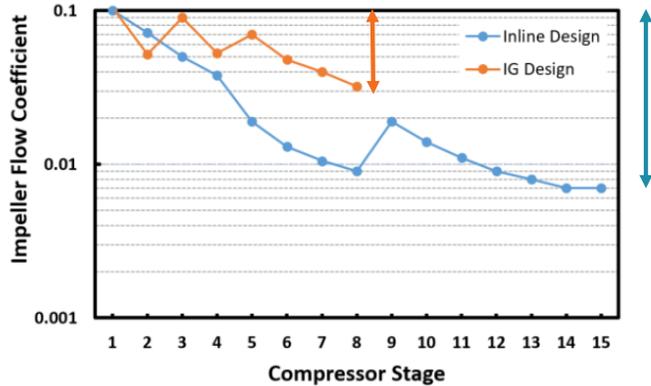
Case Study for 200tons/h dry CO2 from 1 to 160bara



- Compression from 1 to >150 bar
- Fewer stages needed for integrally geared compressors



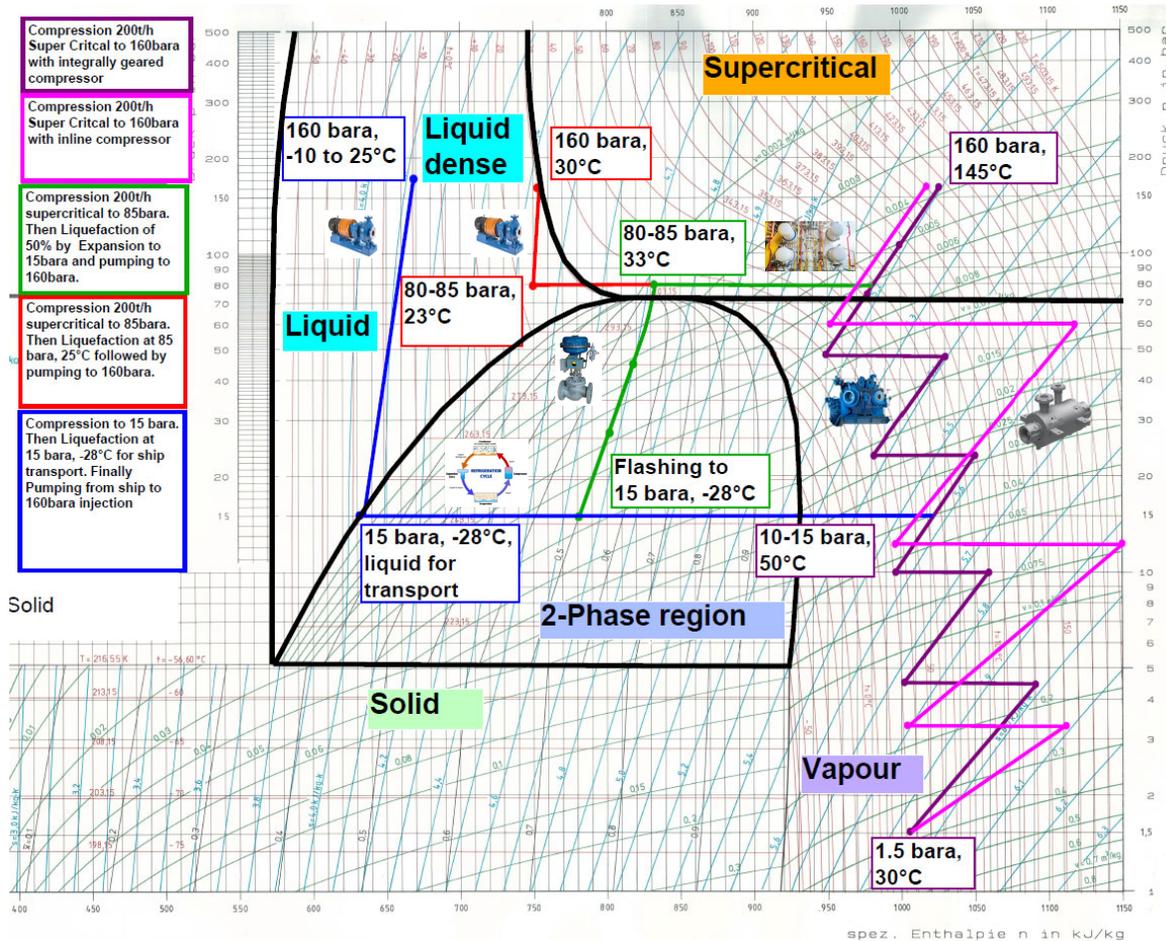
# CCS / CCU – Inline & integrally geared compression



$$\phi = \frac{4 \dot{V}}{\pi \cdot d_2^2 \cdot u_2} \quad h_p \sim \Psi u_2^2 \quad u_2 = \pi n d_2$$

- Volumeflow reduction at higher pressure must be compensated by decreasing diameters, which means loss in head
- Limits in diameter reduction lead to loss of efficiency due to low flow coefficients at higher pressure
- Adapting speed with each pinion for IG-compressor compensates for head and efficiency losses
  - Results: 9% higher efficiency and 17% less power using IGCs

# CCS / CCU – Different processing methods

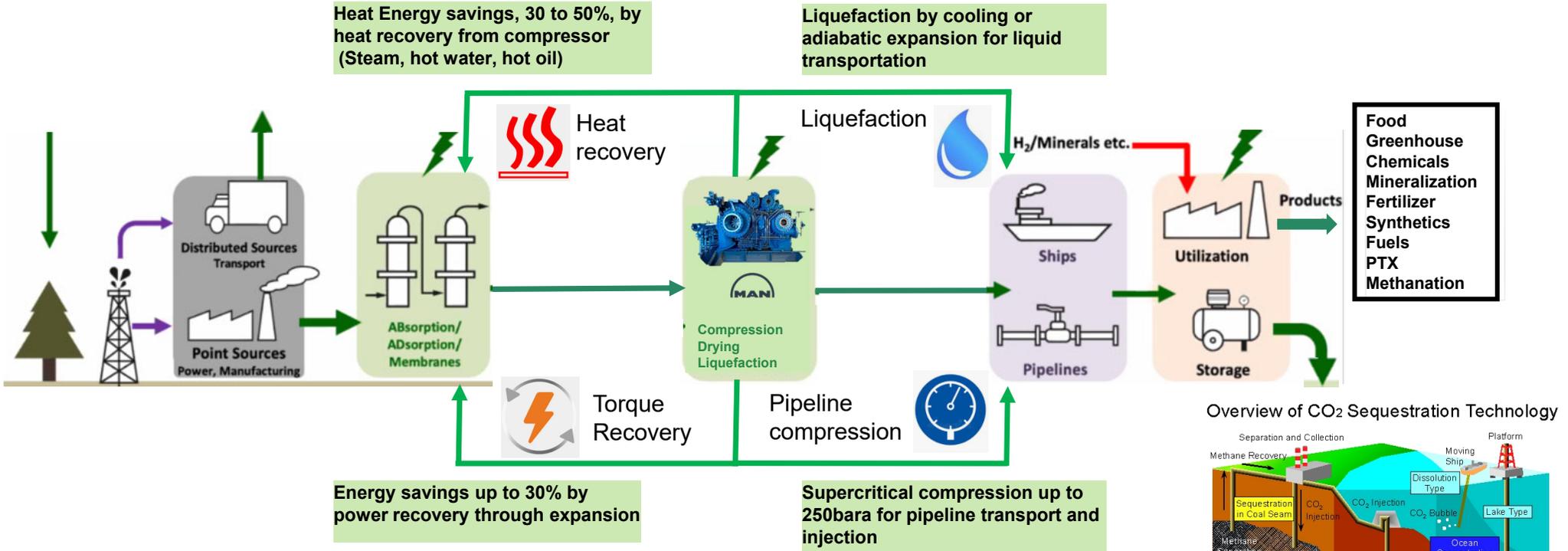


## Decision depends on:

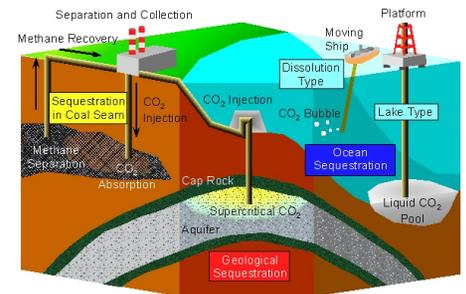
- Infrastructure, means of transport
- Magnitude of CO<sub>2</sub>-flow
- Geography (proximity to water, mountains, deserts)
- Distance to storage location
- Population density, Environmental, geological and political conditions
- Flexibility

# CCS / CCU

MAN solutions to reduce CO<sub>2</sub> costs



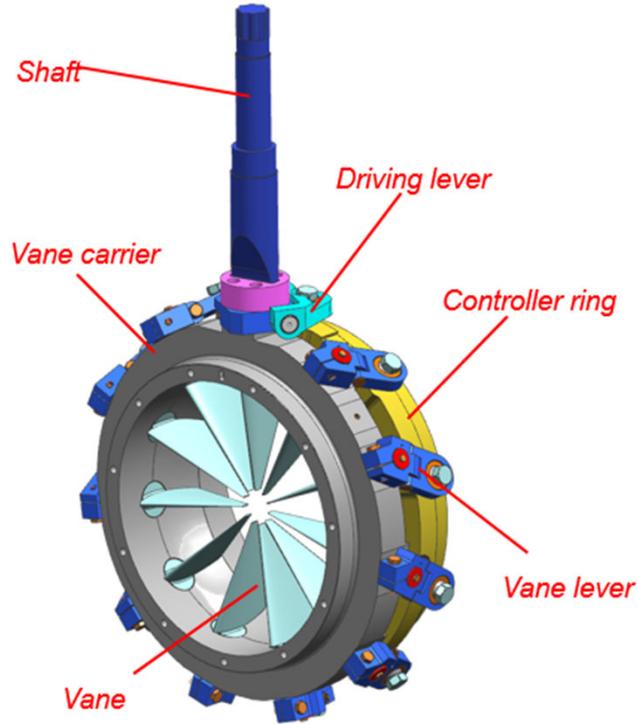
Overview of CO<sub>2</sub> Sequestration Technology



# Integrally Geared Compressor RG



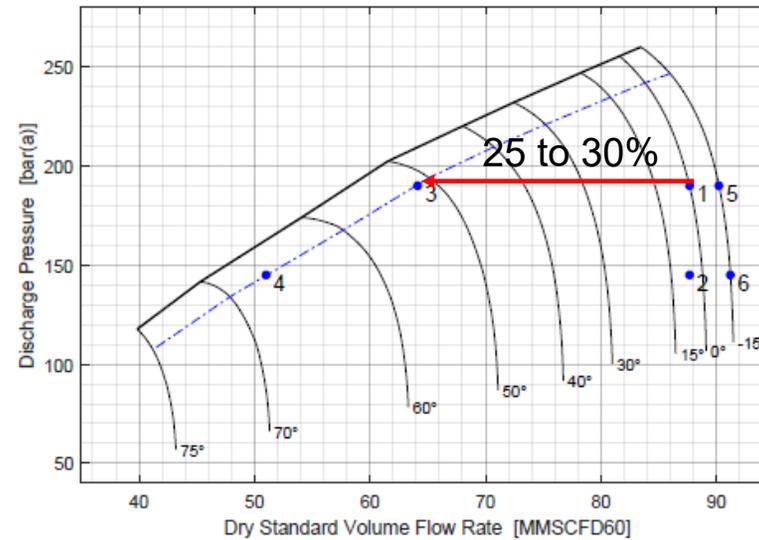
## Inlet Guide Vane



## Predicted Performance Curves RG 80-8



| Section: 1                | Operating Case: DESIGN           | IGV-Angle Variation*               |
|---------------------------|----------------------------------|------------------------------------|
| <b>Gas at Inlet</b>       | <b>Boundary Conditions**</b>     | <b>Performance Map Limitations</b> |
| Description: CO2          | Suction Pressure: 1.300 bar(a)   | Max. Dis. Pressure: n/a bar(a)     |
| Molar Mass: 42.21 kg/kmol | Suction Temperature: 43.30 °C    | Max. Mass Flow: n/a kg/h           |
| Rel. Humidity: 100.0 %    | Intercooling Temp.: $T_{ICs}$ °C | Max. Power: n/a kW                 |
| Isentropic Exp.: 1.282 -  | Driver Speed (100%): 1485 rpm    | Min. Pressure Ratio: n/a -         |



### Operating Points

|          |   |
|----------|---|
| <b>1</b> | 2026-190 Bara<br>87.667 MMSCFD60<br>190.000 bar(a)      |
| <b>2</b> | 2026-145 Bara<br>87.667 MMSCFD60<br>144.996 bar(a)      |
| <b>3</b> | Min Flow - 190 Bara<br>64.13 MMSCFD60<br>190.000 bar(a) |
| <b>4</b> | Min Flow - 145 bara<br>51 MMSCFD60<br>145.001 bar(a)    |
| <b>5</b> | Max Flow - 190 bara<br>90.2 MMSCFD60<br>190.002 bar(a)  |
| <b>6</b> | Max Flow - 145 bara<br>91.2 MMSCFD60<br>144.992 bar(a)  |

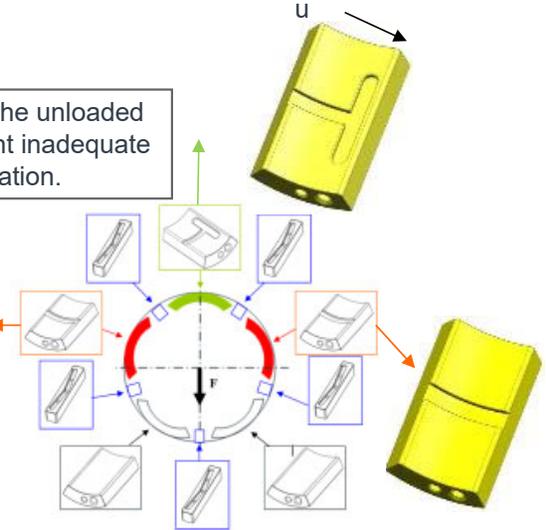
# Components of IG Compressors - Bearings



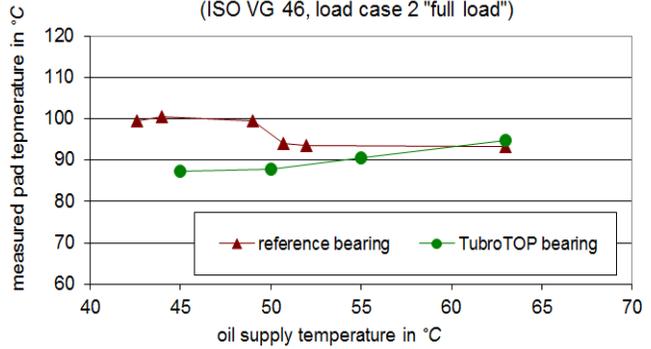
Cooling grooves on rear of pads.

T-groove in the unloaded pad to prevent inadequate lubrication.

Radial grooves to increase the cold oil flow leaving the pad and to reduce the hot-spot risk.



Measured Pad Temperatures on an Integrally Gear Compressor (ISO VG 46, load case 2 "full load")



MAN developed an improved radial tilting pad bearing for high speed pinions:

- ✓ Improved heat removal of the bearing
- ✓ Improved mixture of the different heated oil film-layers
- ✓ Improved start-up behaviour
- ✓ Stiffness and damping criteria on same level

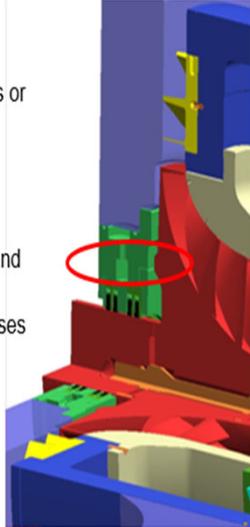
# Components of IG Compressors- Sealing



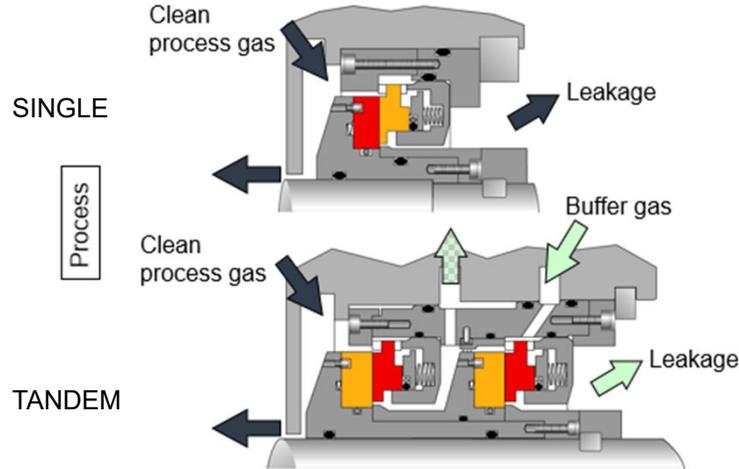
## Carbon ring seals

### Shaft seals

- Each stage requires a shaft seal
- Options are labyrinth seals, carbon ring seals or dry gas seals
- Seal selection depends on process gas and permissible leakages:
  - Labyrinth seals for low pressure air
  - Carbon ring seals for air, nitrogen, CO2 and toxic gases
  - Dry gas seals for toxic and flammable gases
- Use of buffer gas is possible

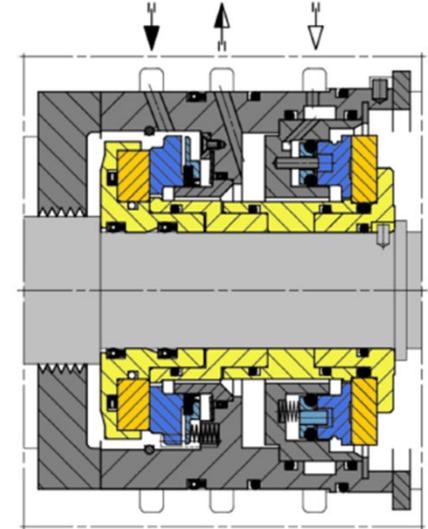


## Dry Gas Seals



Source: Flowserve

## SINGLE with COBA SEAL



PDGS Single CobaSeal © EagleBurgmann

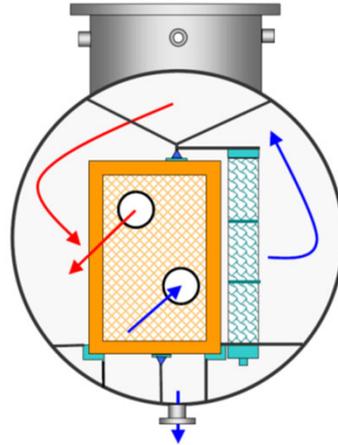
# Components of IG Compressors - Coolers



- Process fluid: shell side up to approx. 50bara
- Cooling fluid: tube side



Element Cooler EKd2.3 with Separator

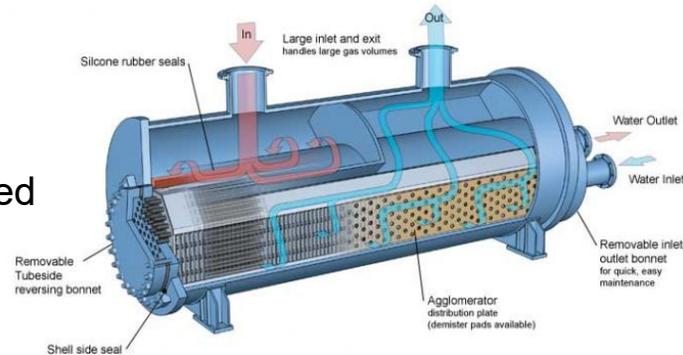


- Process fluid: tube side for pressure >50bara
- Cooling fluid: shell side



For wet CO<sub>2</sub>:

- Bare tubes
- Tubes seal-welded



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# IG Compressors – Modularization



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# 30 years of CO2 References



# Disclaimer



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This data serves informational purposes only and is especially not guaranteed in any way. Depending on the subsequent specific individual projects, the relevant data may be subject to changes and will be assessed and determined individually for each project. This will depend on the particular characteristics of each individual project, especially specific site and operational conditions.

Thank you  
very  
much!

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