

MAN Energy Solutions

How AM supports the decarbonization of hard to abate sectors
MAN ES Integrally Geared Compressor

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Head of R&D Integrally Geared Compressors
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MAN Energy Solutions is part of Volkswagen Group



Sites across Europe and Asia – 14.000 employees worldwide – headquarter in Augsburg

9

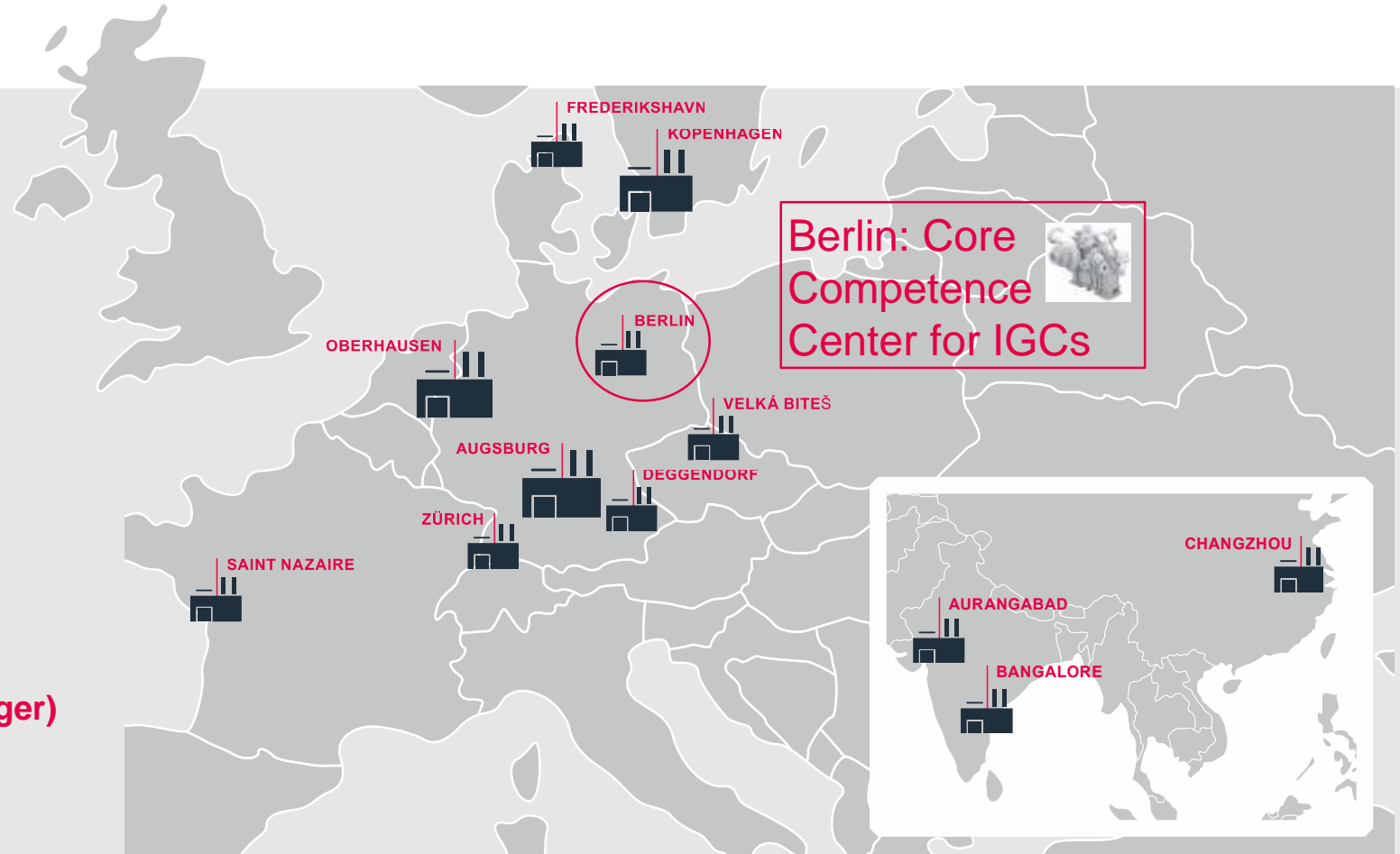
Production sites
in Europe

3

Production sites
in Asia

30

Licensees in 7 countries
(two- and 4-stroke, turbocharger)



Additive Manufacturing for MAN ES Integrally Geared Compressor

- 1 Sustainability & MAN ES strategy**
- 2 Motivation for application of AM**
- 3 Outlook**

Our Purpose

What we do and why we do it

Moving big things to zero

We engineer systems for deep decarbonization in sectors that matter most

Focus RG compressor, Berlin

Heat pumps

Decarbonization of heat supply in industry and households



Carbon Capture

Solutions for unavoidable process emissions and carbon cycles



PEM-Elektrolysis

Where electrification stops, H₂ will play a crucial role



Green propulsion

CO₂-neutral propulsion systems for shipping and power generation



Retrofits

Decarbonization of our customers' existing fleets

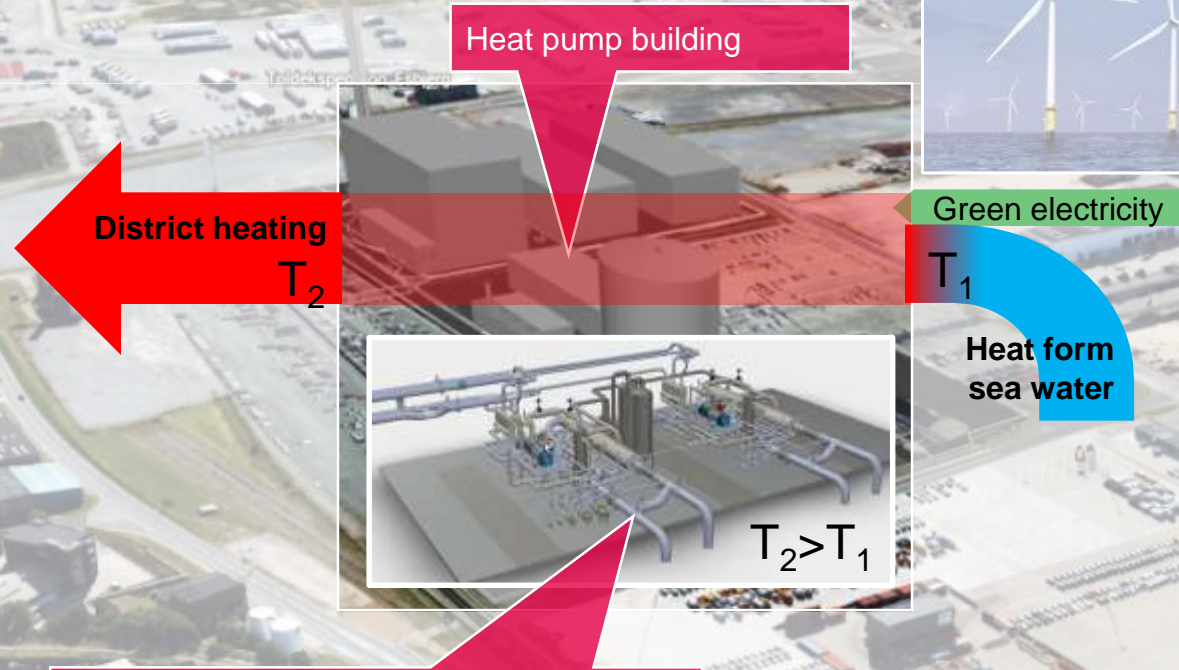


Decarbonization & digitalization are the drivers of our strategic development into an energy solutions provider

Esbjerg at a glance

Sea water heat pump substitutes coal fired power plant

Heat pump = electrification of heat generation



MAN-Heat pump
incl. assembly and commisioning

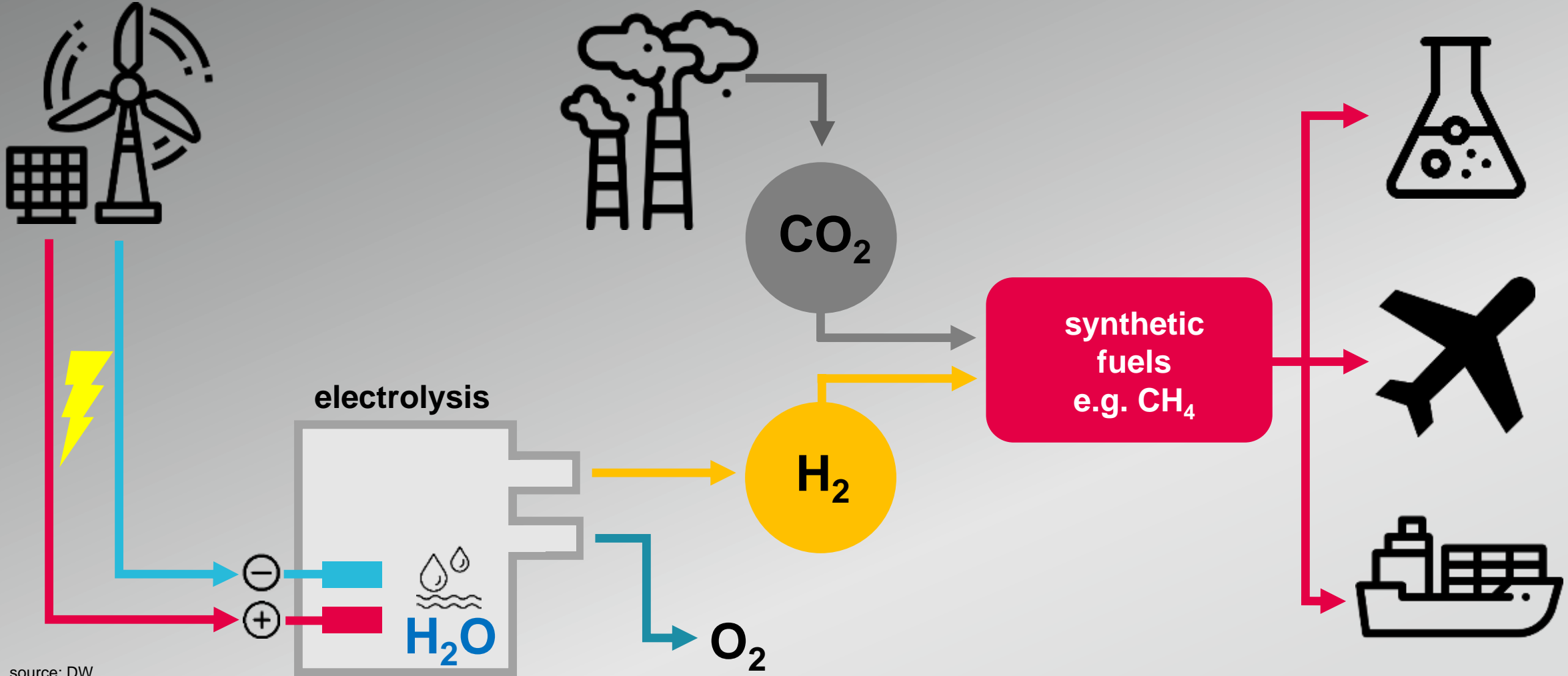


- Facts & figures:**
- District heating for 25'000 households
 - CO₂ savings: 100'000 tpa
 - CO₂ tax savings = ~ 120 Mio € (18 Years)
- Sucess factors:**
1. Environment friendly refrigerant CO₂
 2. Compact environmental friendly, reliable technology well known from O&G industry
 3. MAN as strong partner with ABB

Hand in Hand: CCU/S and the hydrogen ramp-up

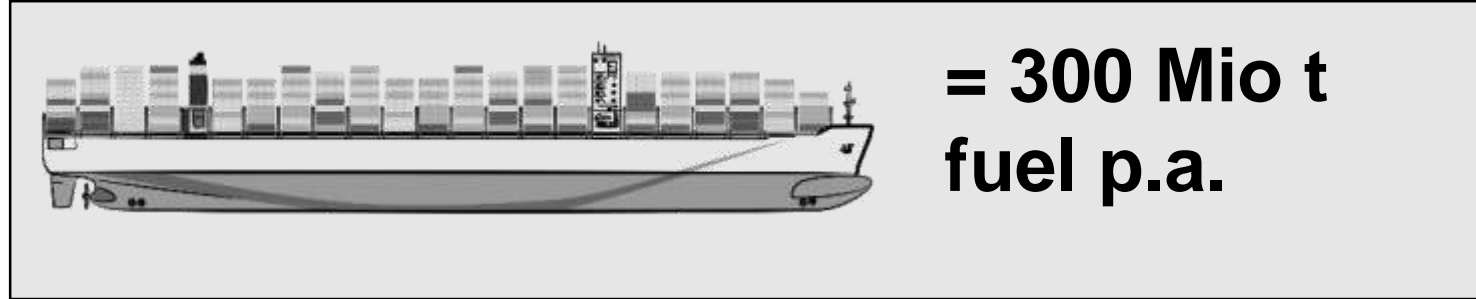


Example: to cover 1% of the annual fuel demand in the shipping industry with synthetic natural gas requires approx. 1 million tons of hydrogen and 7 million tons of CO₂.



source: DW

What is needed to decarbonize maritime transport?



117 Mio t H₂

857 Mio t CO₂

CO₂ and H₂ needs to produce 300 Mio t green methanol

■ CO₂ ■ H₂

What is needed to decarbonize aviation industry?



= 331 Mio t
Kerosene p.a.

145 Mio t H₂

1025 Mio t CO₂

CO₂ and H₂ needs to produce 300 Mio t green Kerosene

■ CO₂ ■ H₂

MAN Energy Solutions: bringing it all together...

"Green" Hydrogen & eFuel Value Chain

MAN Energy Solutions
CO₂-Compressors



MAN Energy Solutions



eFuel Reactors & Process Technology

MAN Energy Solutions



SNG Compressors & LSNG-to-Power Infrastructure Solutions



Renewable Energy



Power-to-Gas Solution
(Full EPC)

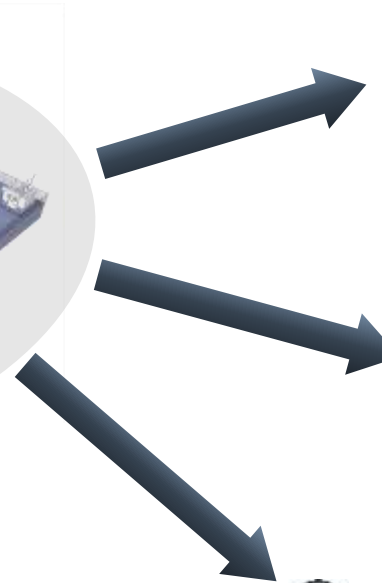


PEM Electrolysers

MAN Energy Solutions

&

Hydrogen e-fuels
H-TEC SYSTEMS



MAN Energy Solutions

Compressors for Blend (H₂/NG) & pure H₂ Grid Structures



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H₂ & eFuel-ready Engines



SNG = Synthetic Natural Gas | LSNG = Liquefied Synthetic Natural Gas

Proof Point: Power-to-SNG in Werlte

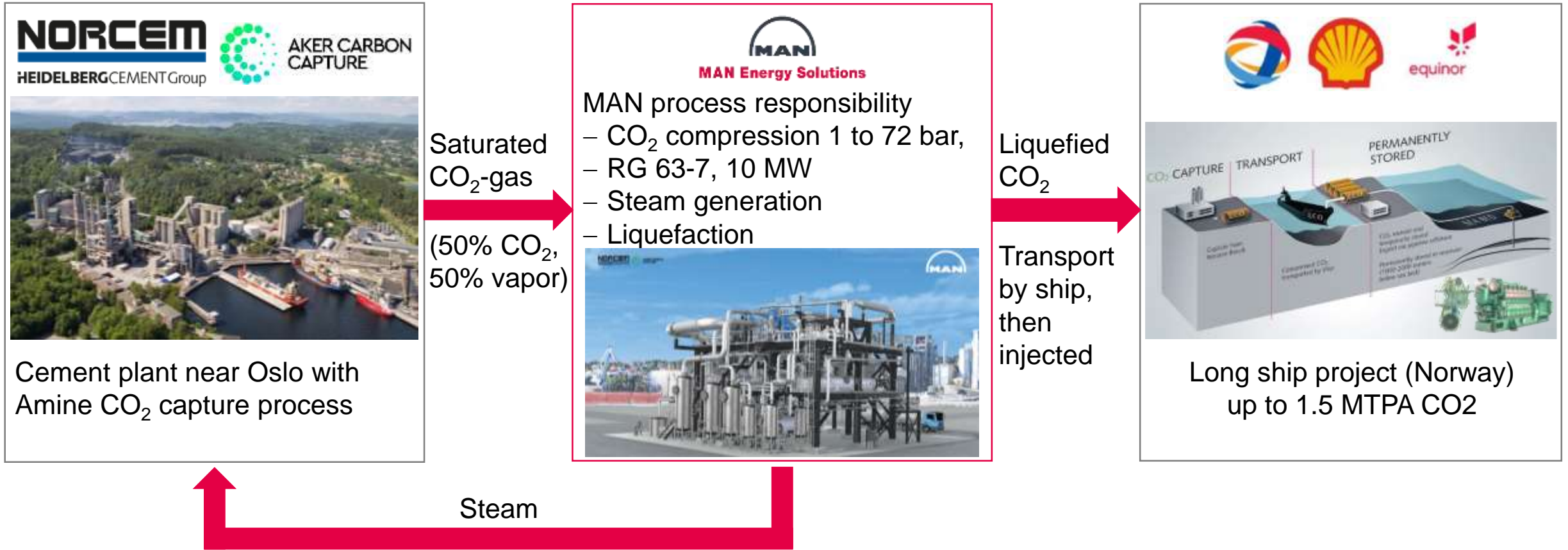
This plant is in operation since 2013 and produces synthetic fuels e.g. for the marine sector



CCU/S solutions – Northern Lights Project

0.4 MTPA \cong  0.2 Mio.

CO2 Compression with Heat Recovery Solution in Cement Industry



Capture and Compression of 0.4 MTPA CO₂, 50 % of plants CO₂ emission, from 1 to 72 bar.
Heat energy savings for capture plant approx. 33% by heat recovery from compressor.

The world of turbomachinery



MAN ES product portfolio

Compressors

various types for any application



- $V_{\max} = 1.5 \text{ mil. m}^3/\text{h}$
- $p_{\max} = 25 \text{ bar}$



- $V_{\max} = 6$
- $p_{\max} = 2$



- $V_{\max} = 690 \text{ T m}^3/\text{h}$
- $p_{\max} = 250 \text{ bar}$

Expander

for power generation and energy



- $T_{\max} = 760 \text{ }^\circ\text{C}$
- $p_{\max} = 25 \text{ bar}$
- $P_{\max} = 30 \text{ MW}$



- $V_{\max} = 30 \text{ T m}^3/\text{h}$
- $p_{\max} = 300 \text{ bar}$



- $V_{\max} = 100 \text{ T m}^3/\text{h}$
- $p_{\max} = 50 \text{ bar}$

S
and mechanical drive



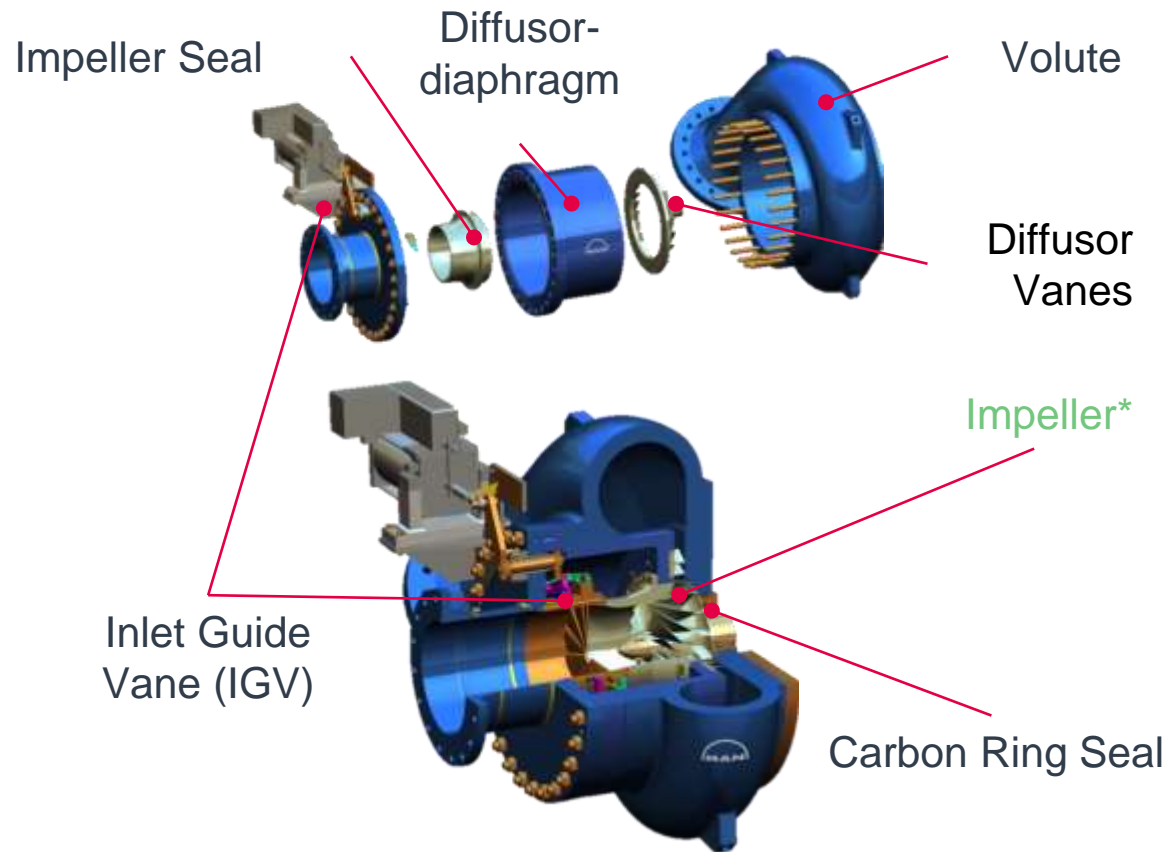
- $P_{\max} = 6-13 \text{ MW}$
- Fuel flexibility (H_2)

Integrally Geared Compressor

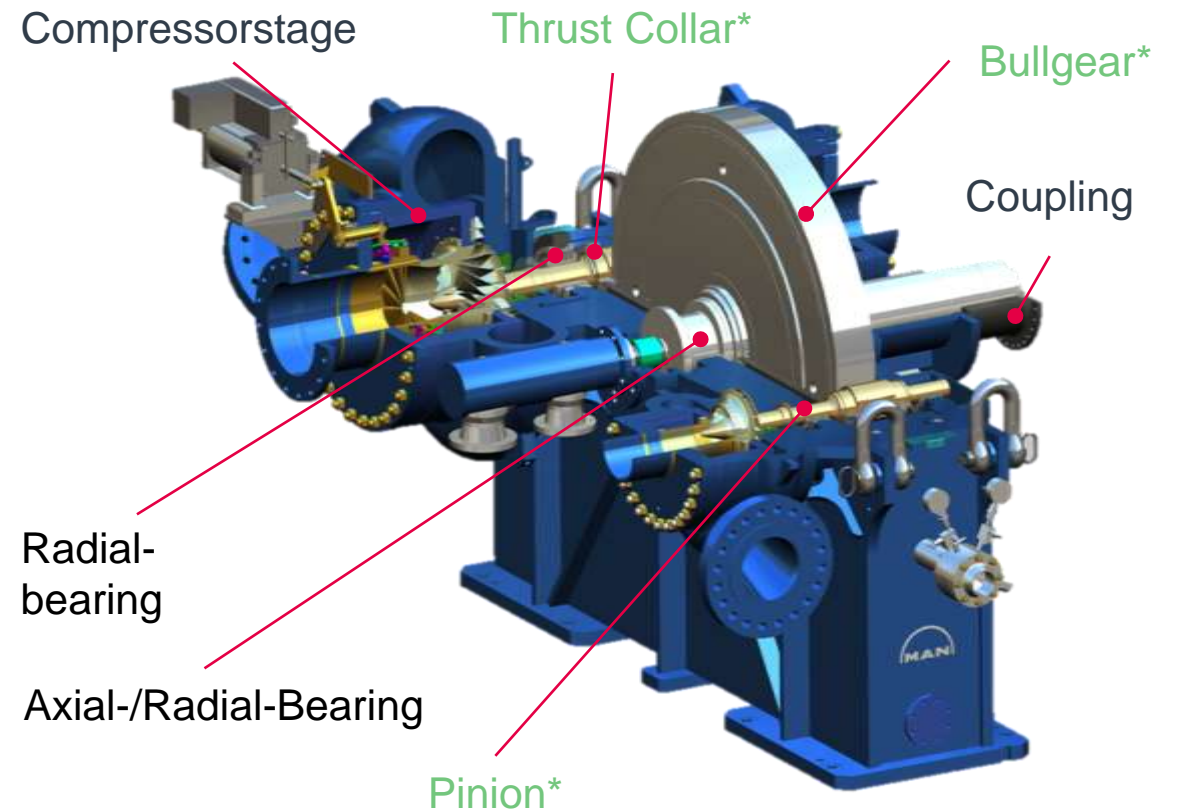
RG Compressor – Main Components



Components of Compressorstage



Gear Box Components



*Inhouse Manufacturing Berlin

Motivation for Additive Manufacturing



Material substitution

Forged raw material not available easily.

Cost & lead time reduction

Reduction of material

Raw material vs. AM powder

Increase of compressor efficiency

Enabler for new solutions

Careful implementation: AM parts have to satisfy conservative customers.

Summary & Outlook

Development requirements



MAN ES

- is at the beginning of AM application for the integrally geared compressor.
- sees significant potential in AM application for total cost optimization (material, fabrication hours and lead time)
- sees high potential in material saving.
- sees AM as enabler of applications like H2-compressor.

Development requirements:

- Increase of feasible downskin faces / reduction of support structures
- Standardized quality testing processes / NDT / process monitoring
- Increase of possible compressor component size for L-PBF
- Improved surface quality & surface modification treatments
- Easy remove of powder material for inner cavities
- Reduced changeover time for AM-machines (change of powder material)
- Cost down of manufacturing costs



Thank you very much!

Anja Dobat
Head of R&D Integrally Geared Compressors
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