Advances in Geothermal Power

Nov 29/30th 2023

Atlas Copco Gas and Process

Introduction

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Education: B.S. General Engineering

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Position: Market Segment Manager New Energy
Office: Atlas Copco Energas, Germany
Education: B.E. Process Engineering

Thank you for the invitation and the great work of the GEMS organizers!

This is the Atlas Copco Group

- Customers in more than **180** countries
- **49 000** employees in **70** countries
- Established in **1873** Stockholm, Sweden
- Turnover of **141** BSEK/ **13.5** BLN USD*
- Operating margin of **21.4%**

*Based on the average exchange rate in 2023.

Atlas Copco

A decentralized Group

BOARD OF DIRECTORS

PRESIDENT AND CEO

GROUP MANAGEMENT

COMPRESSOR TECHNIQUE

- Compressor Technique Service
- Industrial Air
- Oil-free Air
- Professional Air
- Gas and Process
- Medical Gas Solutions
- Airtec

VACUUM TECHNIQUE

- Vacuum Technique Service
- Semiconductor Service
- Semiconductor
- Semiconductor Chamber Solutions
- Scientific Vacuum
- Industrial Vacuum

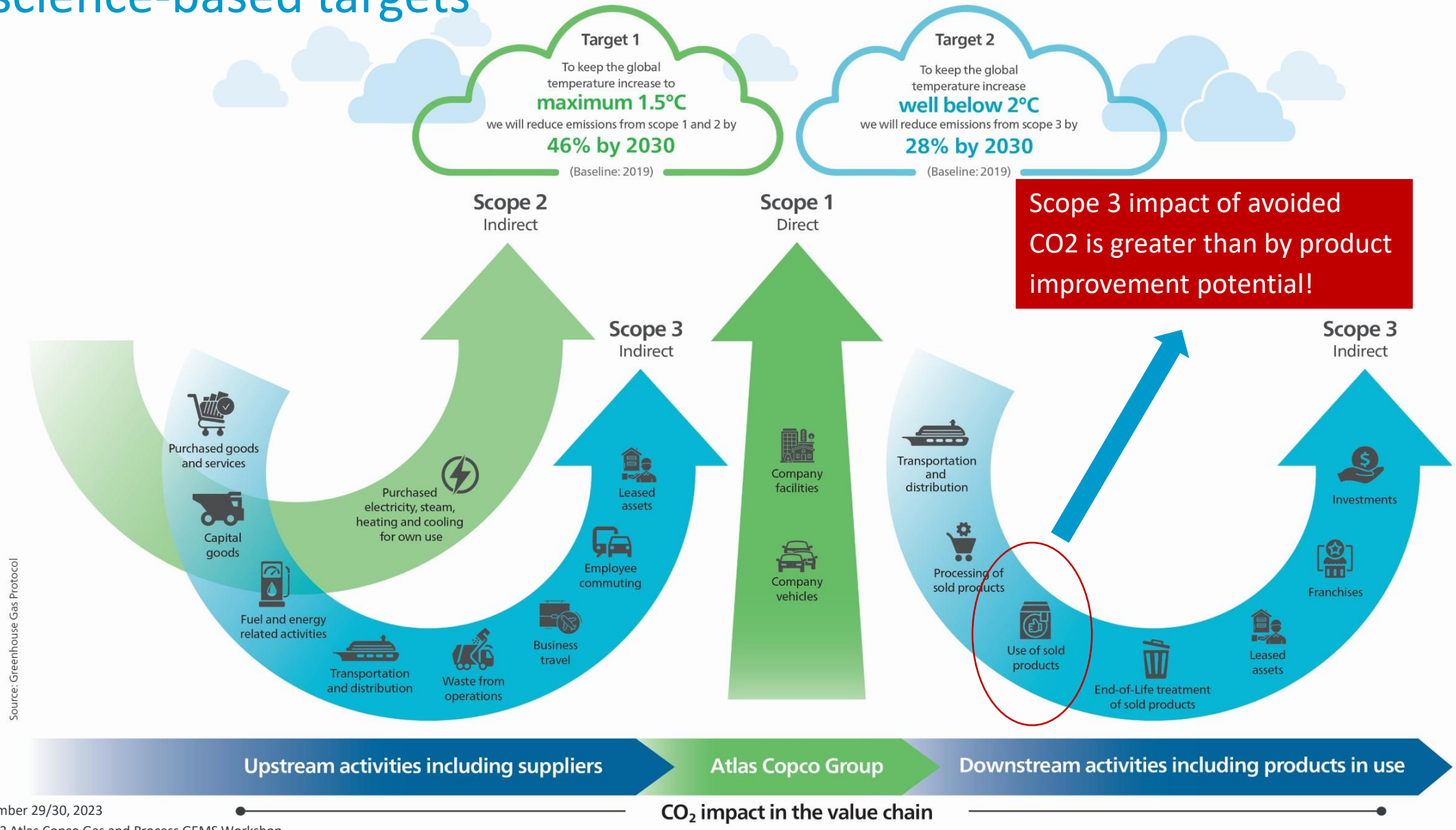
INDUSTRIAL TECHNIQUE

- Industrial Technique Service
- MVI Tools and Assembly Systems
- General Industry Tools and Assembly Systems
- Chicago Pneumatic Tools
- Industrial Assembly Solutions
- Machine Vision Solutions

POWER TECHNIQUE

- Power Technique Service
- Specialty Rental
- Portable Air
- Power and Flow

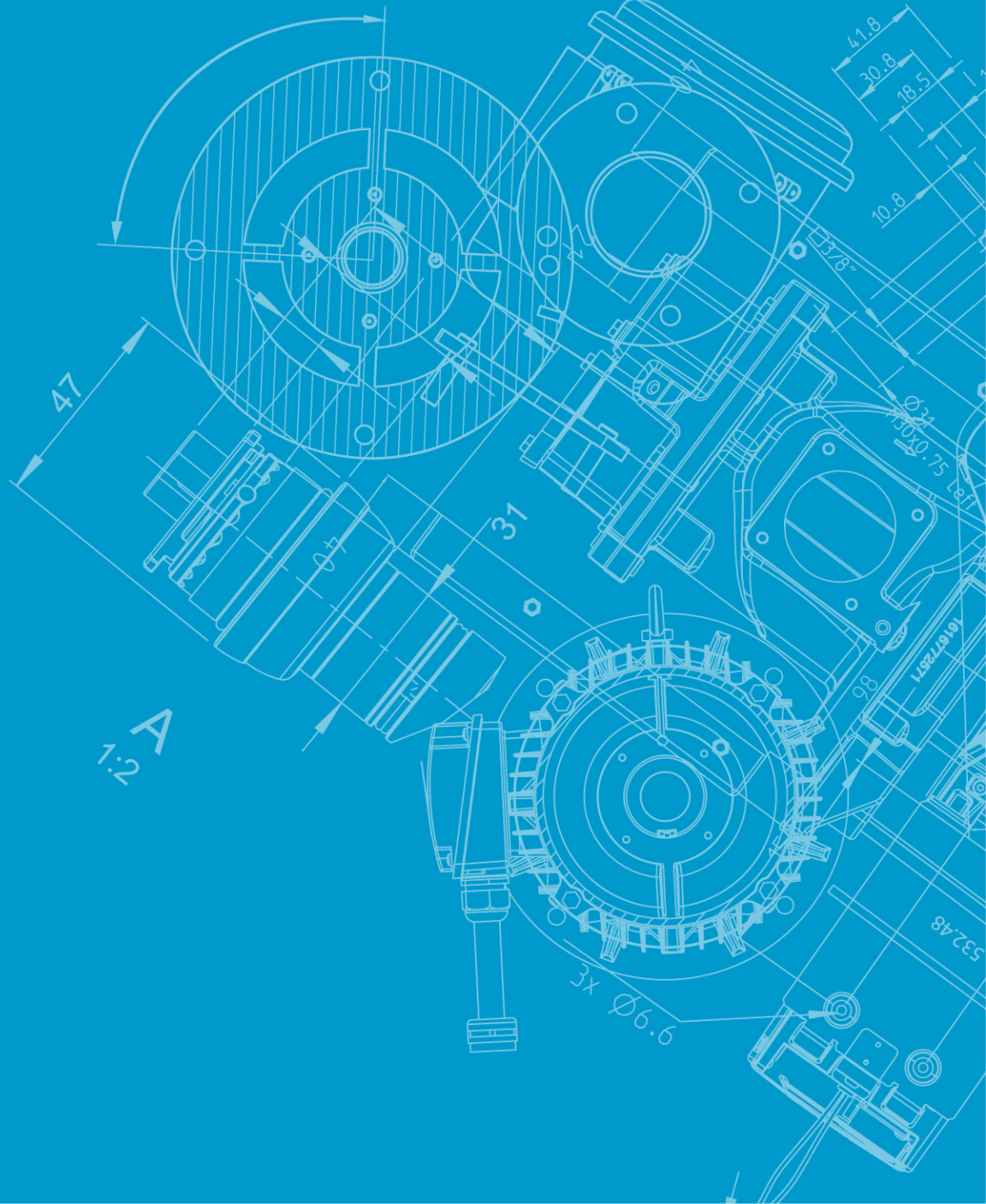
Our science-based targets



Scope 3 impact of avoided CO2 is greater than by product improvement potential!

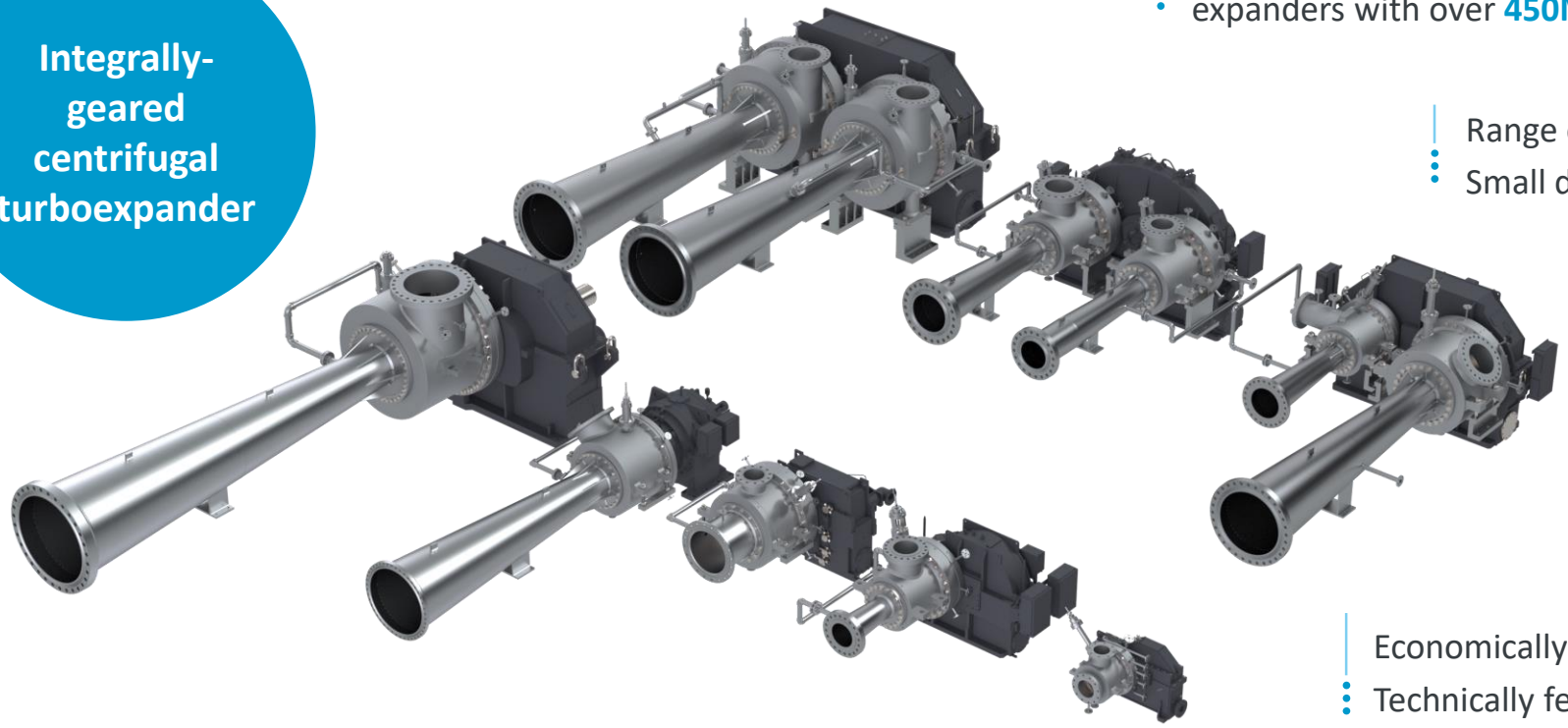
Integrally geared ORC Expanders

Reliable and mature technology for power generation



Product overview | Expanders for ORC Geothermal Power Plants

Integrally-geared centrifugal turboexpander



Atlas Copco is the only EPC-independent major brand for ORC expanders with over **450MW** in more than **35** installations

Range of **8 Frame Sizes** covers wide power range from Small demo plants to >30MW full-commercial

Integrally geared design allows compact and flexible multistage units (parallel, HP/LP etc).

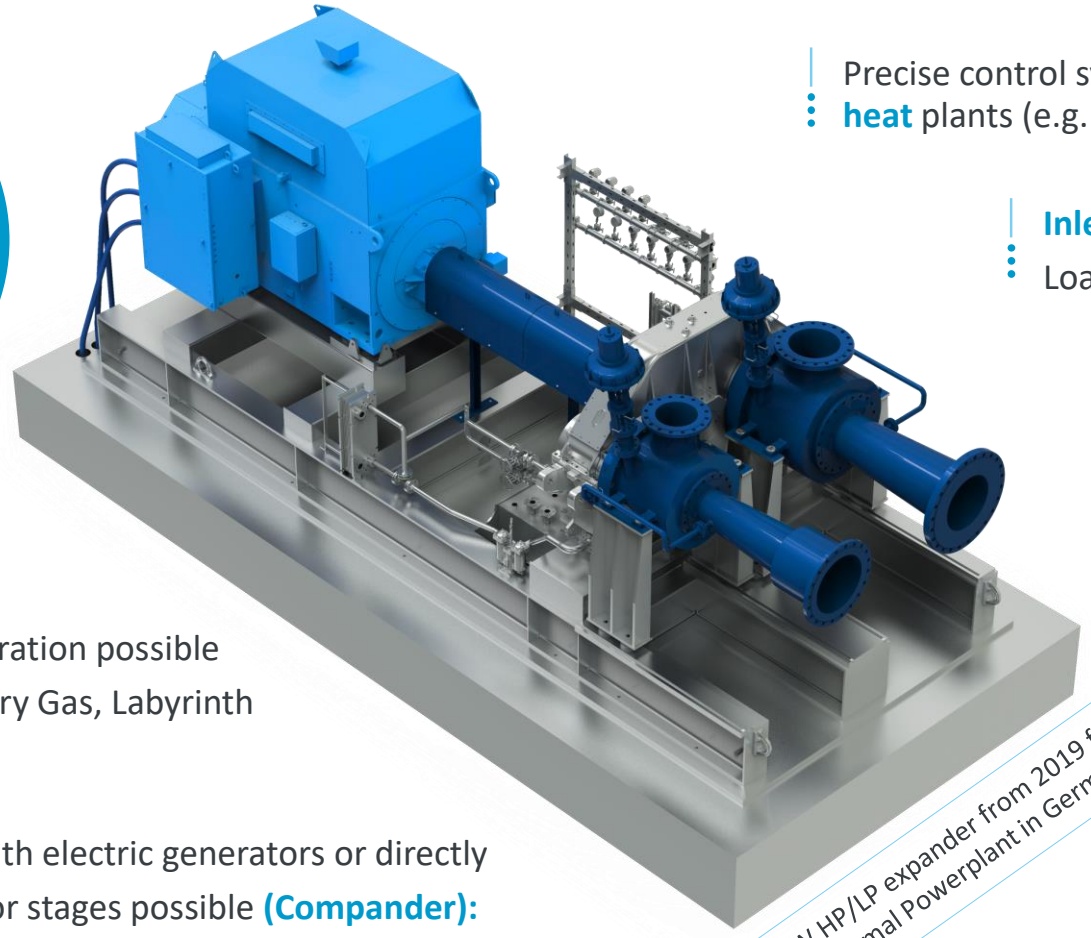
Custom designed and CFD optimized Impeller designs for **highest efficiencies**

Economically viable power range is **5 to 30MW,** Technically feasible power range is **500kW to 40MW**

Mature technology with documented **availability >98% p.a.,** due to continuous design improvement and implementation of “lessons learned”

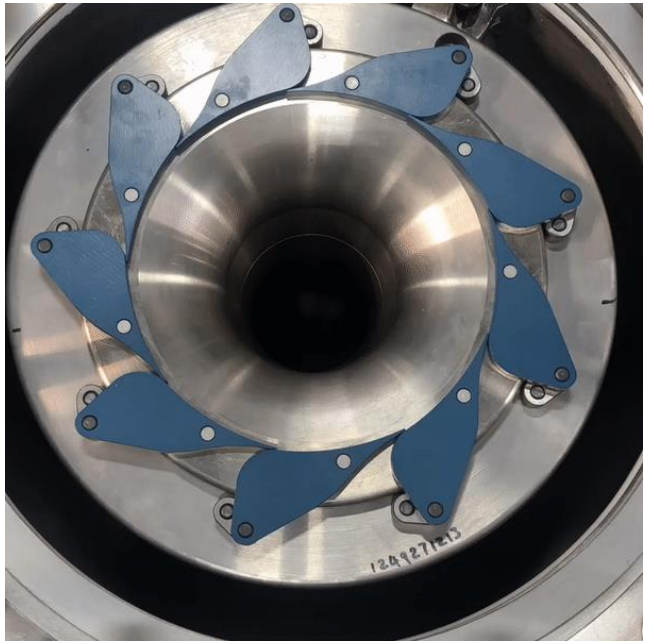
Product overview | Expanders for ORC Geothermal Power Plants

Integrally-geared centrifugal turboexpander



5MW HP/LP expander from 2019 for Geothermal Powerplant in Germany

- Precise control system allows **combined geothermal power and heat** plants (e.g. district heating and surplus heat-to-electricity)
- **Inlet guide vane** technology allows precise and fast Load and frequency control including “island mode”
- Zero leakage configuration possible
- **Shaft sealings:** Oil, Dry Gas, Labyrinth
- Configurations with electric generators or directly driven compressor stages possible **(Compander):**
  Example: High pressure process steam from low-temperature geothermal resources by steam compressor!



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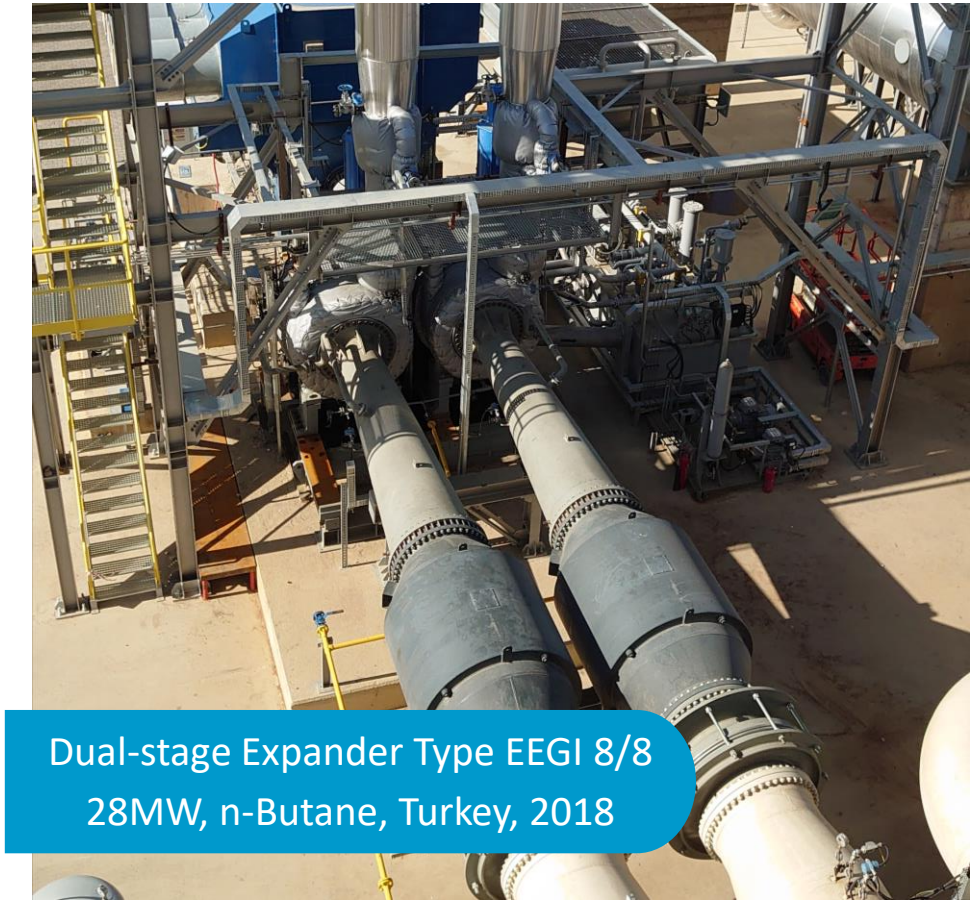
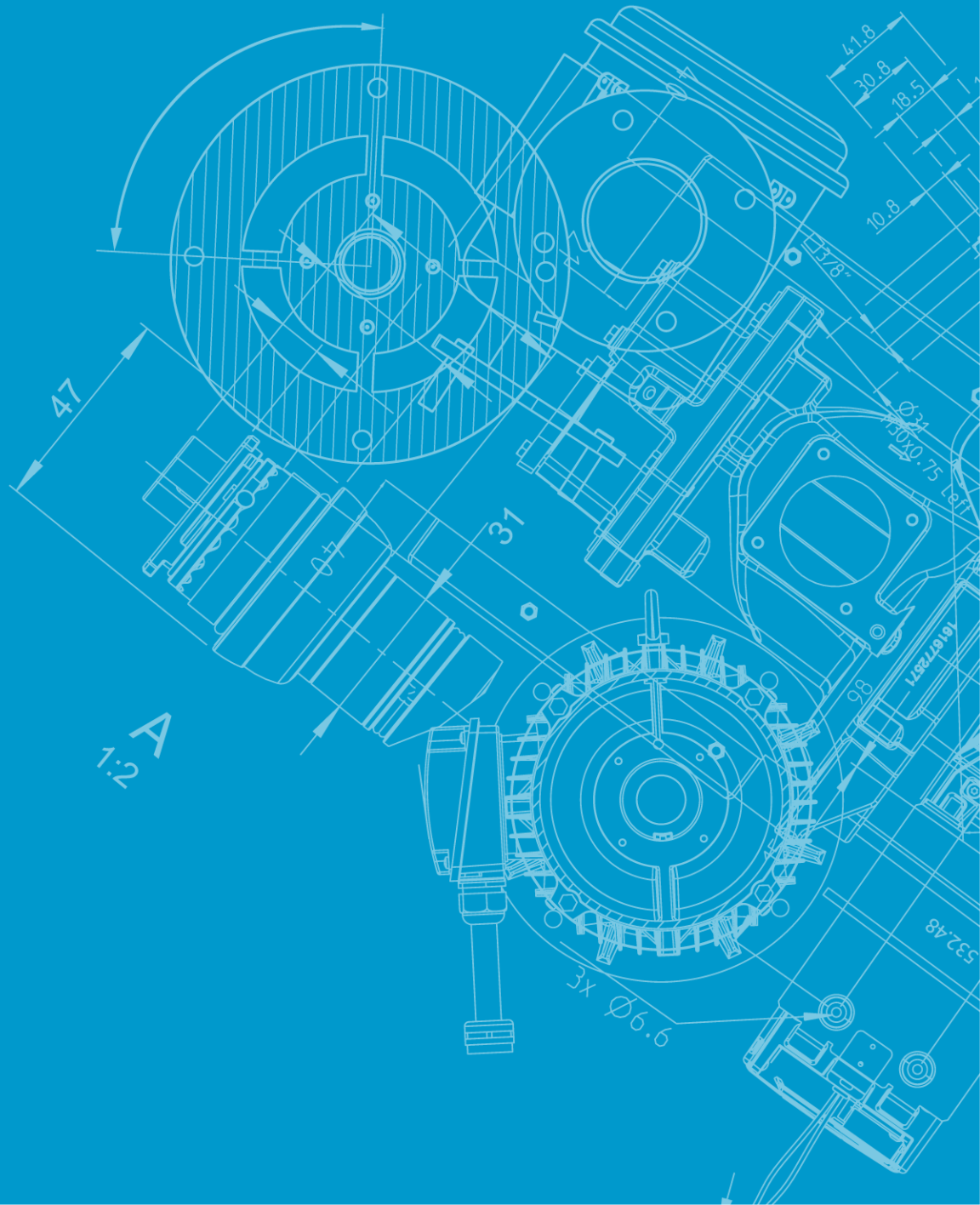


Dual-stage Expander Type EEGI 8/8
28MW, n-Butane, Turkey, 2018

Single-stage Expander Type EGi 8
13MW, i-Butane, USA, 2007

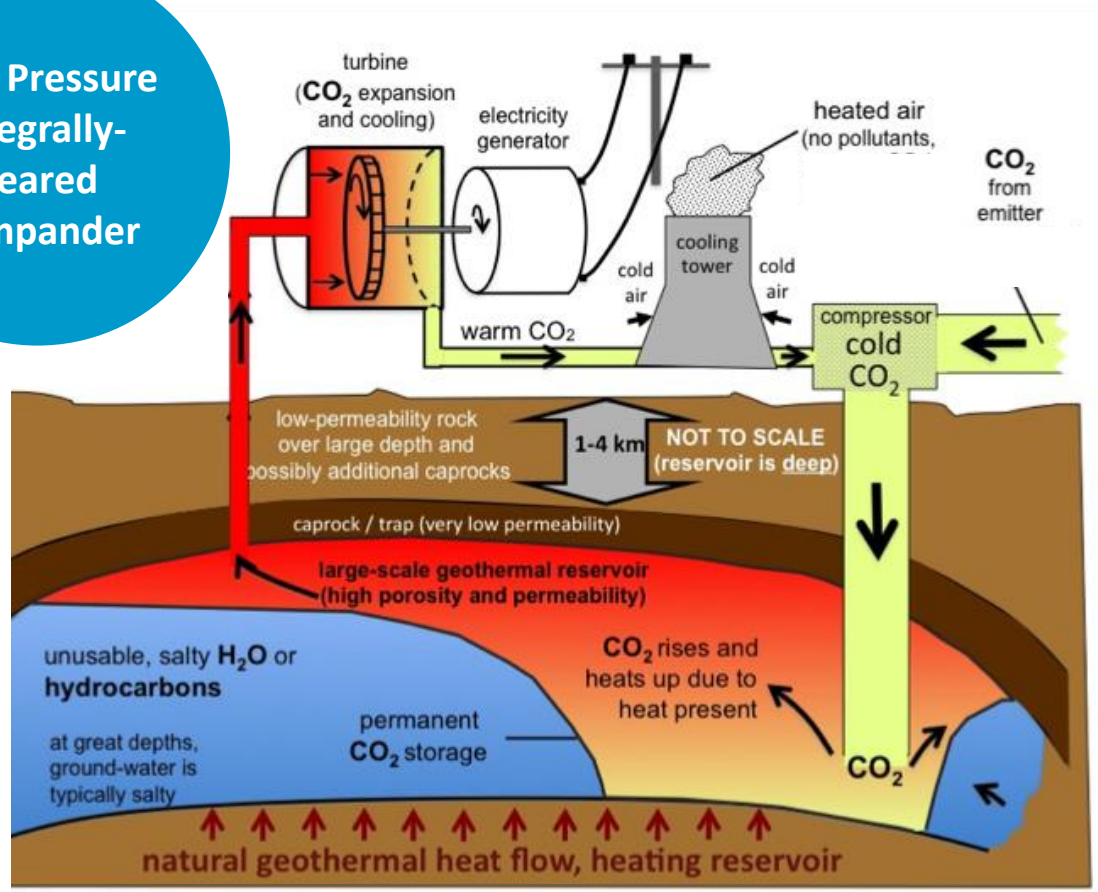
Supercritical Fluids Expanders

The next frontier in power generation



Product overview | Expanders for Advanced / sCO2 Power Plants

High Pressure Integrally-geared Compander

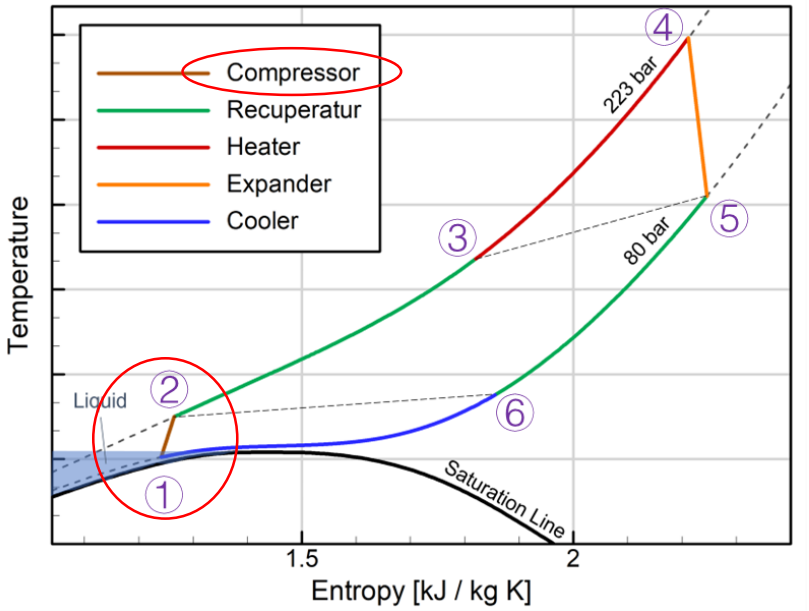


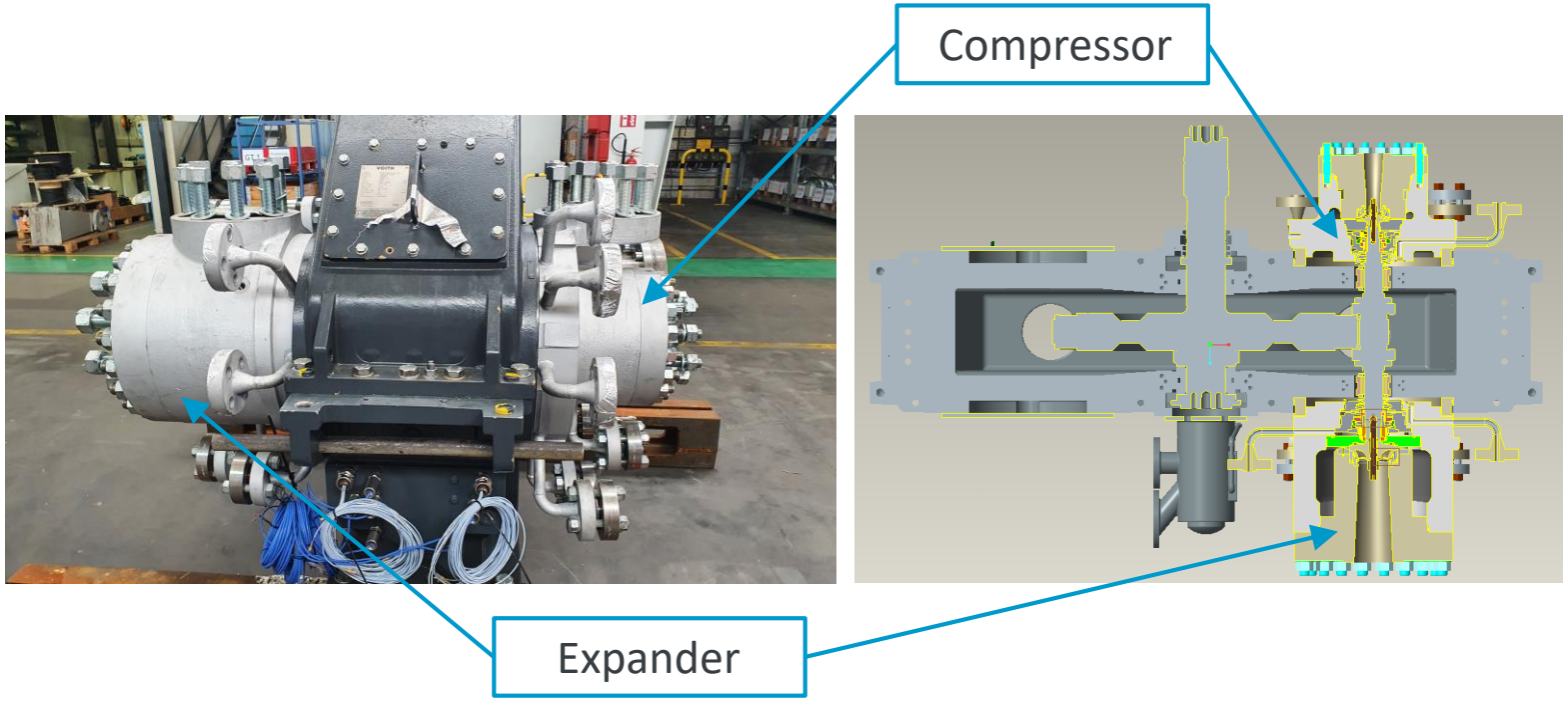
Copyright: Randolph and Saar, 2011a

- Advances in **geothermal resource engineering** allow direct use of CO2 as working fluid
- Geothermal power production, combined with **carbon dioxide storage** is very suitable for oil&gas producing areas
- Modern Geothermal Powerplants may use directly **CO2** or other **supercritical** fluids
- **Trace components** (Cl, H2S) often present in reservoirs, As well as methane etc., posing corrosion threads to metals

Product overview | Expanders for Advanced / sCO2 Power Plants

High Pressure Integrally-geared Compander





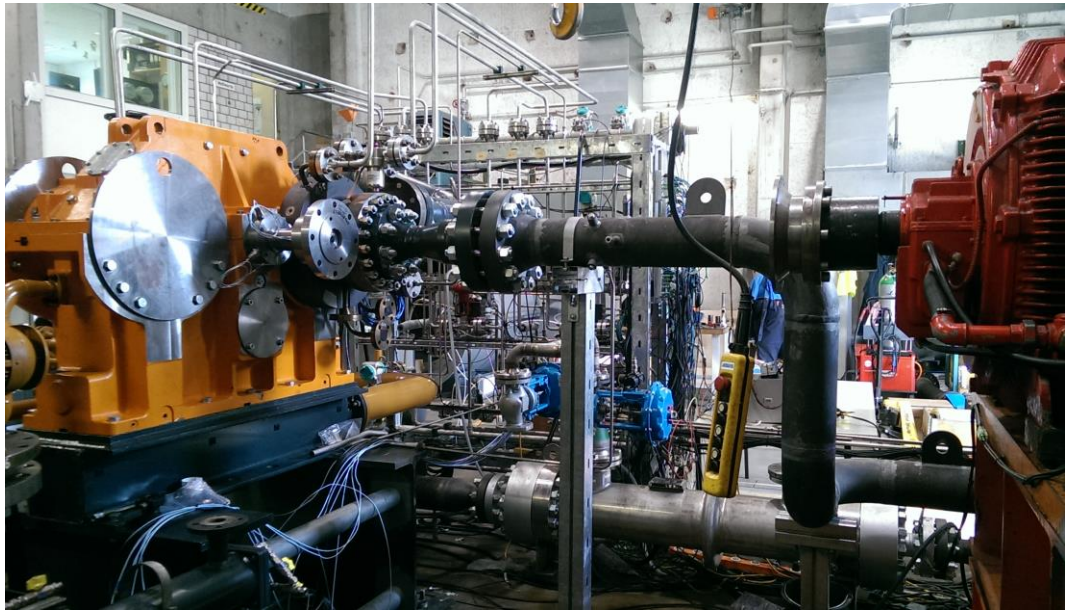
- **Supercritical power cycles (CO2)** require other setup than ORC powerplants – instead of feed pump, there is a feed compressor
- Extreme high pressures (>200bar / >3000PSI) and **high power density** require other machine designs, compared to ORC expanders.

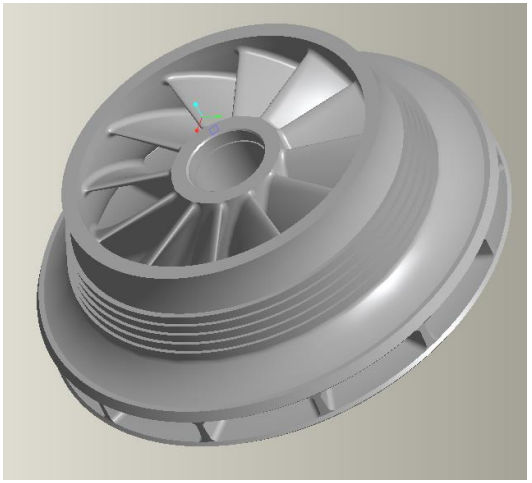
Product overview | Expanders for Advanced / sCO2 Power Plants

High Pressure Integrally-geared Compander

- High pressure compressor and expander design for power cycle **successfully tested**
- Approximately **10-times higher power density,** compared to ORC expanders

Impeller type	**centrifugal, shrouded**
Shaft sealing	Dry Face Seal
Impeller diameter	150 Millimeter / 6 inch
Speed	38 000 RPM
Mass flow	174 600 kg/h / 385 000lb/h
Inlet pressure	220 bara / 3190 PSIA
Inlet temperature	275°C / 530°F
Outlet pressure	82 bara / 1190 PSIA
Expander power	3528 kW / 4730 hp



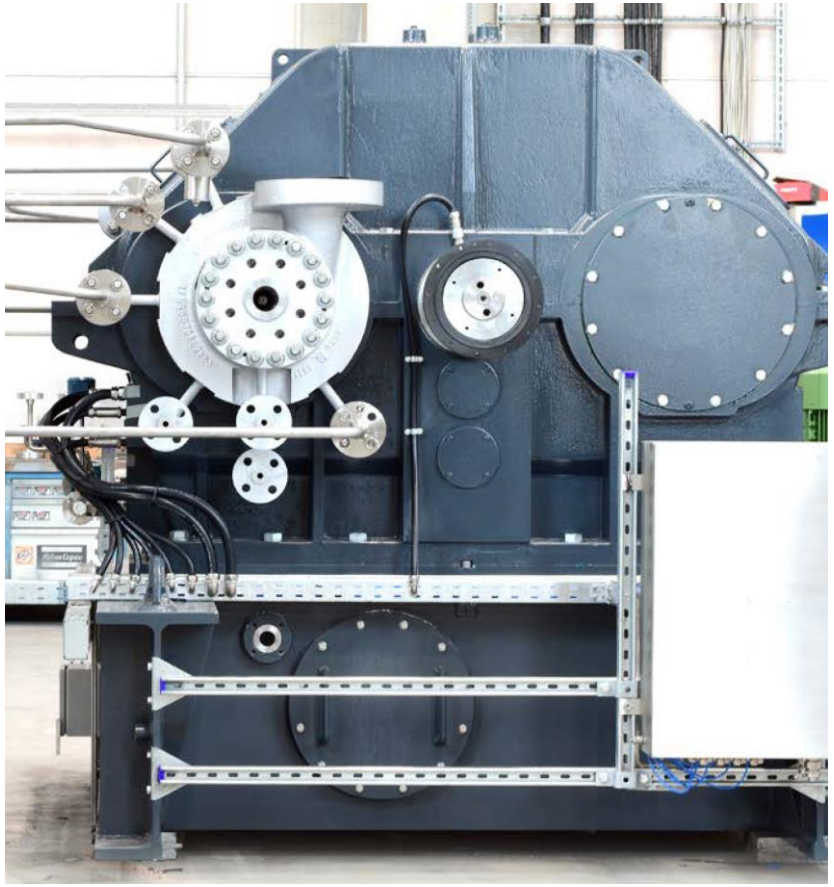


- Design can be **freely modified** for severe fluid / corrosion requirements
- Still not used in a wide scale, as ORC Technology is more mature and investors are risk-averting….

Product overview | Expanders for Advanced / sCO2 Power Plants

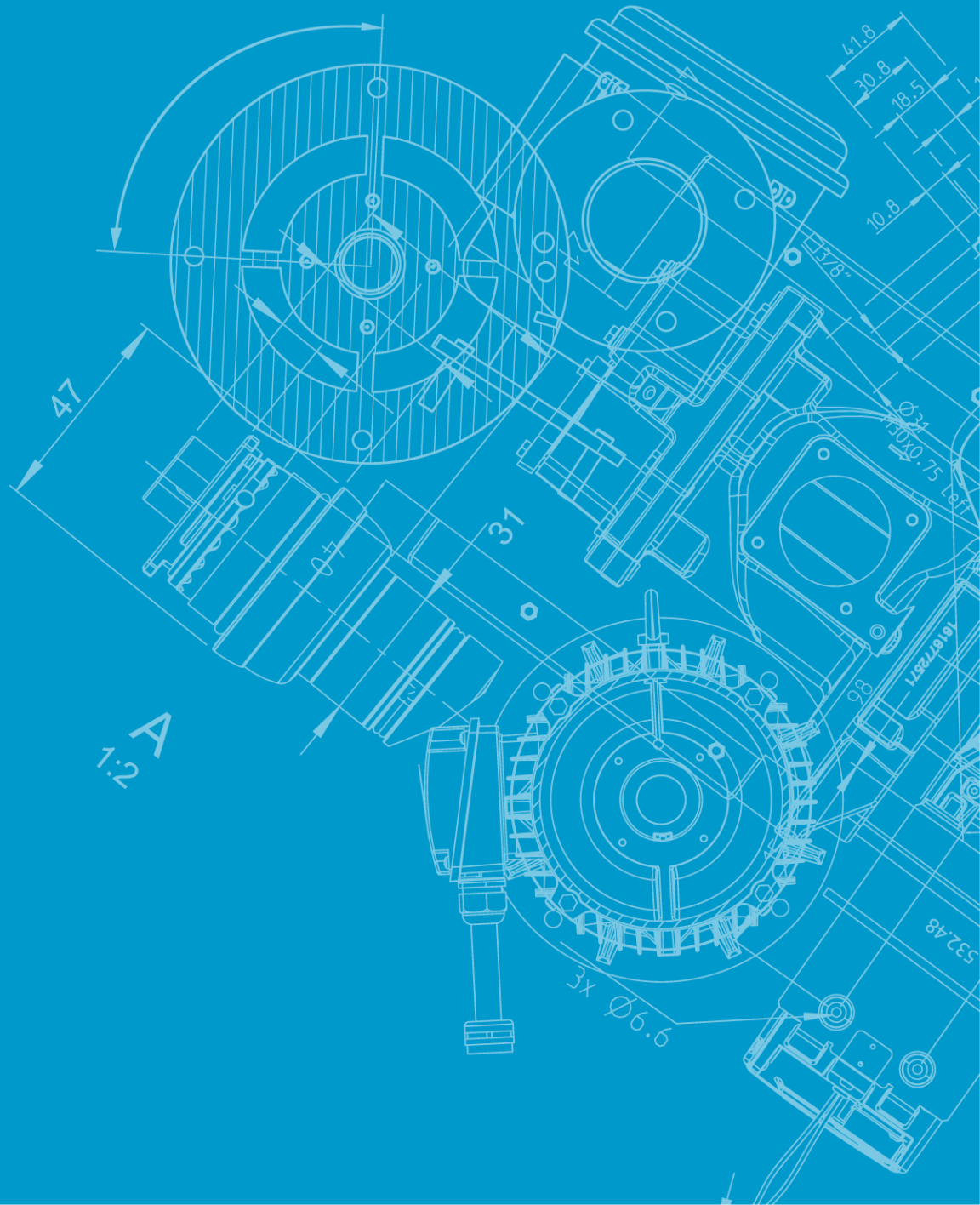
High Pressure Integrally-geared Compander

- sCO2 expander-compressor technology is ready for **plant sizes** up to approx. 10MW
- Shown **demo unit is for sale**, ask us in case of interest!



Steam Generation

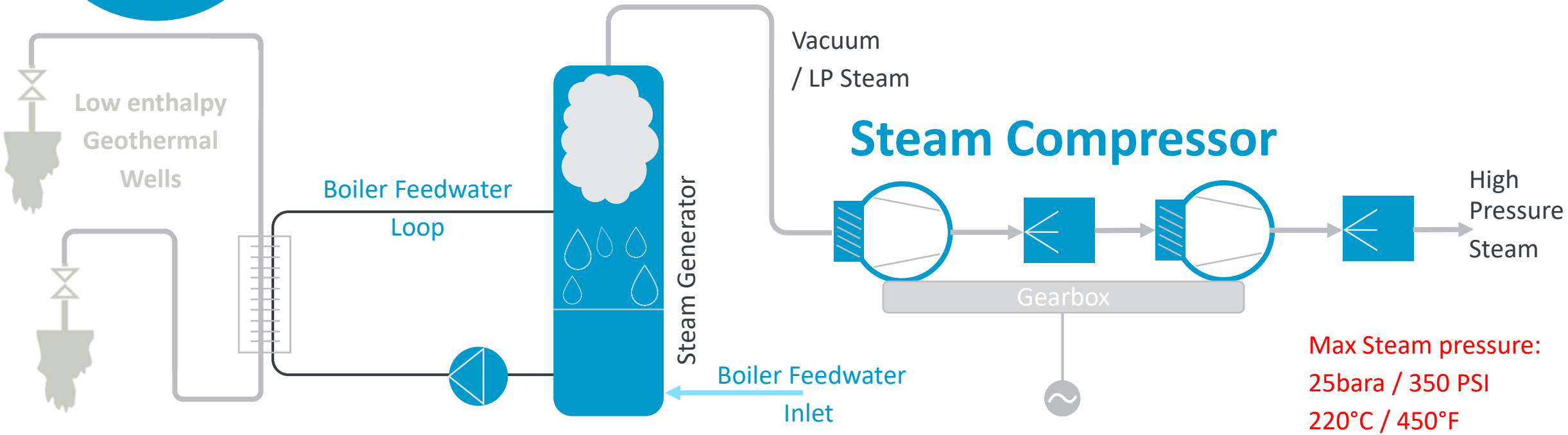
Industrial heat from geothermal resources



Product overview | Compressor for industrial heat generation

Integrally-geared Steam Compressor

- **Direct use** of **geothermal** heat is more efficient (>90%) than electric power generation (10-20%)
- Low enthalpy sources can be used for direct **steam generation**
- Steam generation by geothermal heat and **subsequent compression** as ideal combination for climate neutral heat
- More than 150 references for Atlas Copco Gas and Process **steam compressors**



Product overview | Compressor for industrial heat generation

Integrally-geared Steam Compressor

- Heat-to-electricity **efficiency (COP)** can be as high as 7
- Very **mature technology** with known processes

Dual-stage Steam Compressor, Type GT032T2K1
1.5MW, 12t/h steam, 30 to 175 PSI

Thank you!
Questions welcome!

Atlas Copco