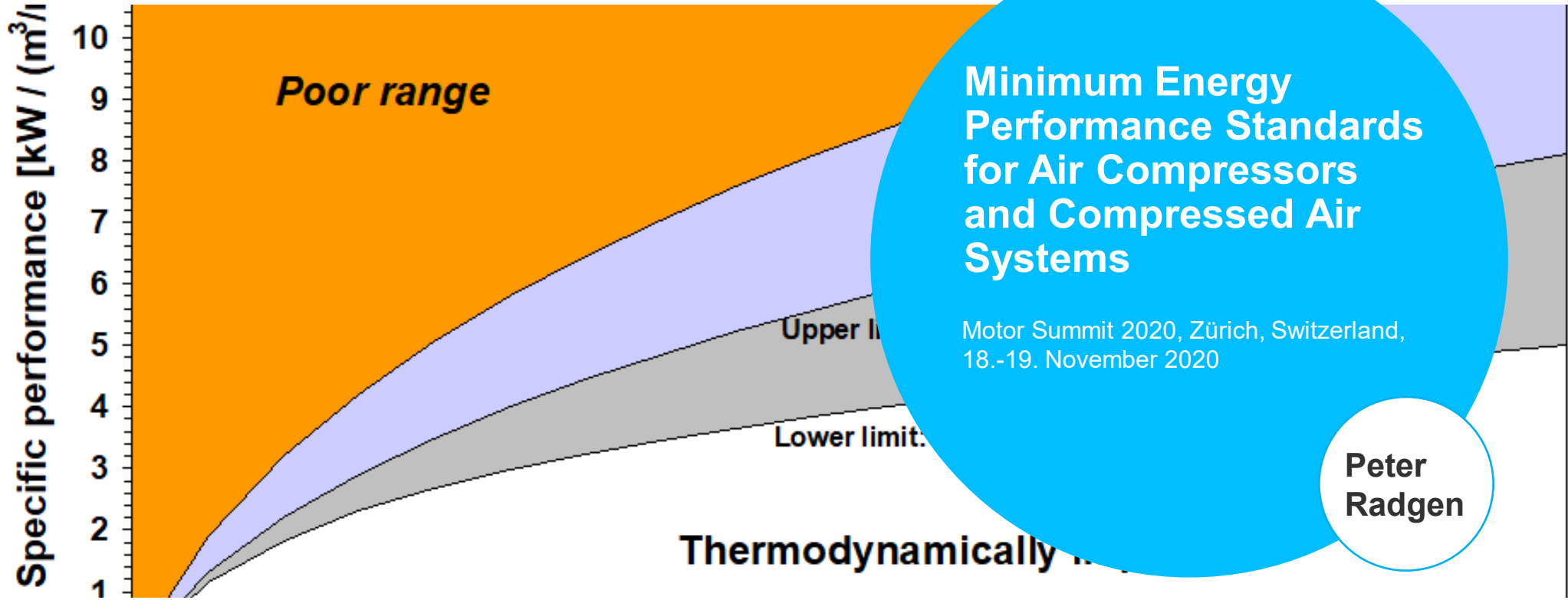


University of Stuttgart

IER

Chair for Energy Efficiency
Institute for Energy Economics and
Rational Use of Energy



Minimum Energy Performance Standards for Air Compressors and Compressed Air Systems

Motor Summit 2020, Zürich, Switzerland,
18.-19. November 2020

Peter Radgen

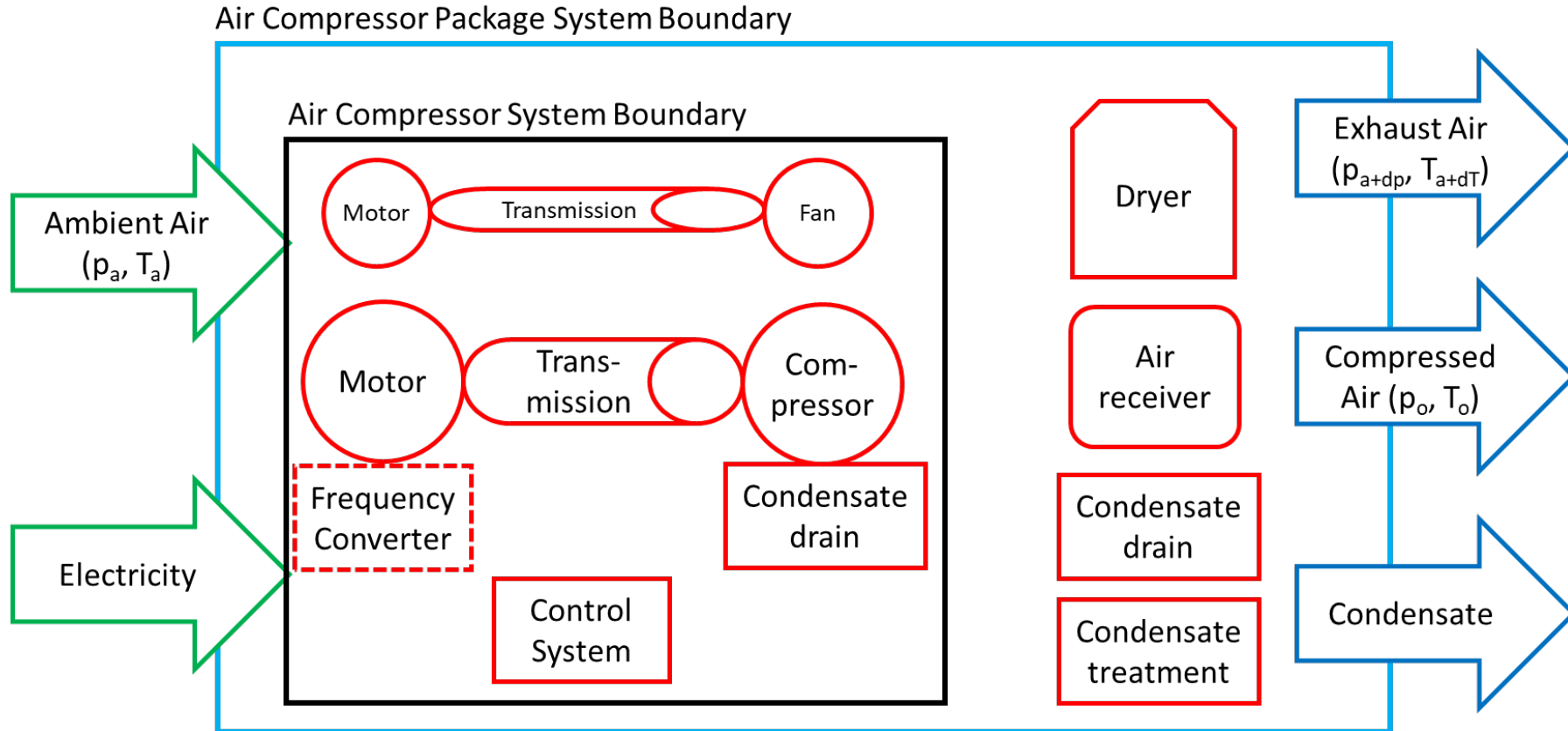
Comparison of Air Compressors

Defining the scope

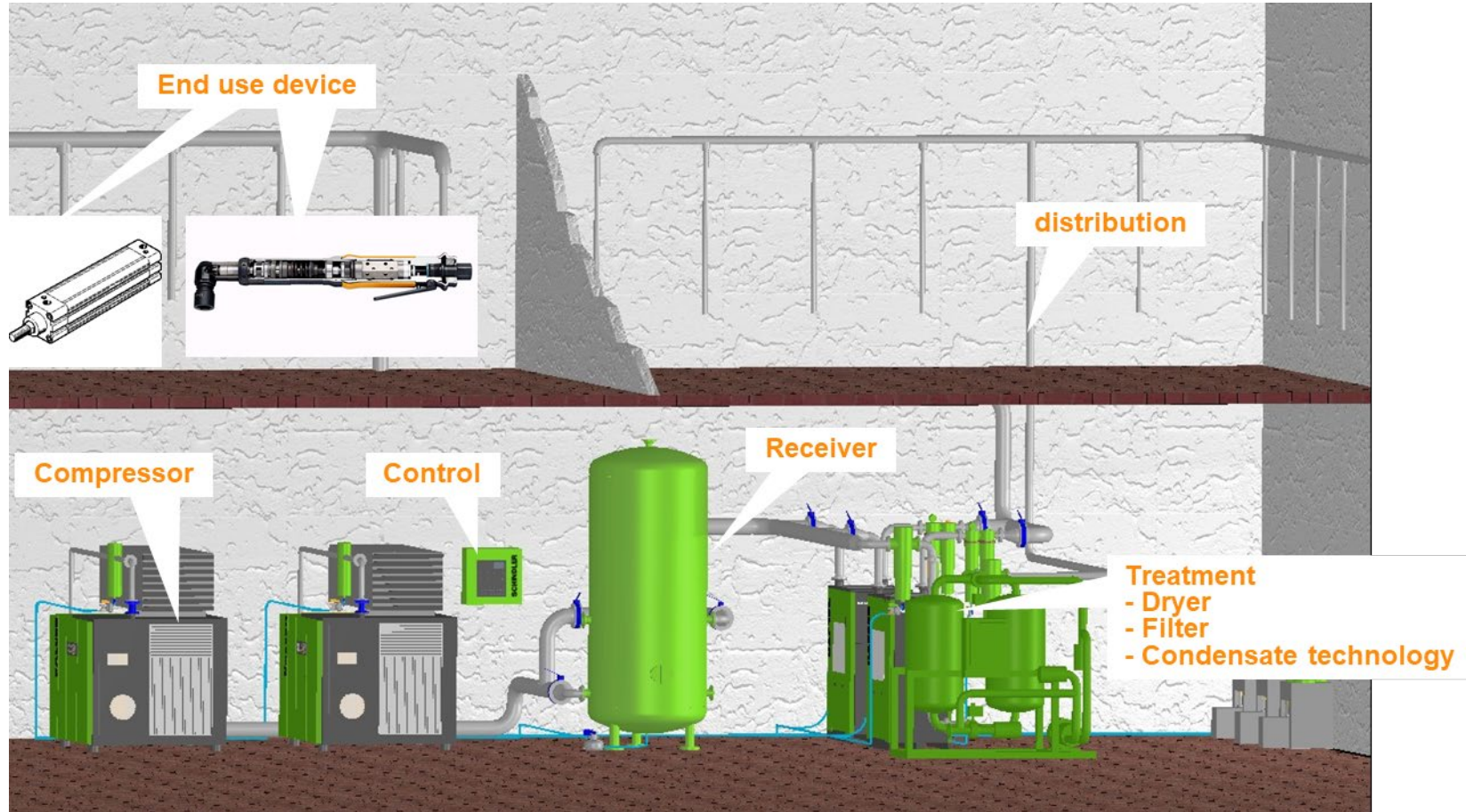
- The first step should always be the clear definition of the system boundary
- For energy related products, the overall efficiency of the system drives the energy consumption and the related CO₂ emissions
- An especially high efficiency of a system component can not compensate for the poor efficiency of other system components.
- The larger the system under consideration the broader the variety of system configurations are getting and therefore comparisons or setting benchmarks becomes highly complex
- Therefore efficiency standards for key components such as air compressors are important, but system aspects should not be overlooked.
- For compressed air systems four different scopes can be investigated: The compressor, the compressor package, the compressor station and the compressed air system.

Air Compressors and Air Compressor Package System boundary

Much more than a compressor



Compressed Air Systems Boundary



What is required – What is delivered ?

How to analyse the efficiency of air compressors

- To analyse the performance of an air compressor, the data provided by manufacturers in the sales brochures do not help at all.
- Typically specified in the brochures are:
 - the mechanical power of the motor for the compressor drive
 - the maximum free air delivery at maximum outlet pressure
- Typically missing in the brochure
 - the specific power consumption according to ISO1217 at different pressures
 - for frequency controlled compressors the specific power consumption according to ISO1217 at different pressures and free air delivery

Manufacturers typically have the full data sheets for the compressors, but unfortunately they are highly reluctant to hand them over. In the US, data sheets of the same manufacturers (CAGI data sheets) are published but are based on 60Hz operation.

The Benchmark for Air Compression

Isothermal and Isentropic compression of an ideal gas

Isothermal

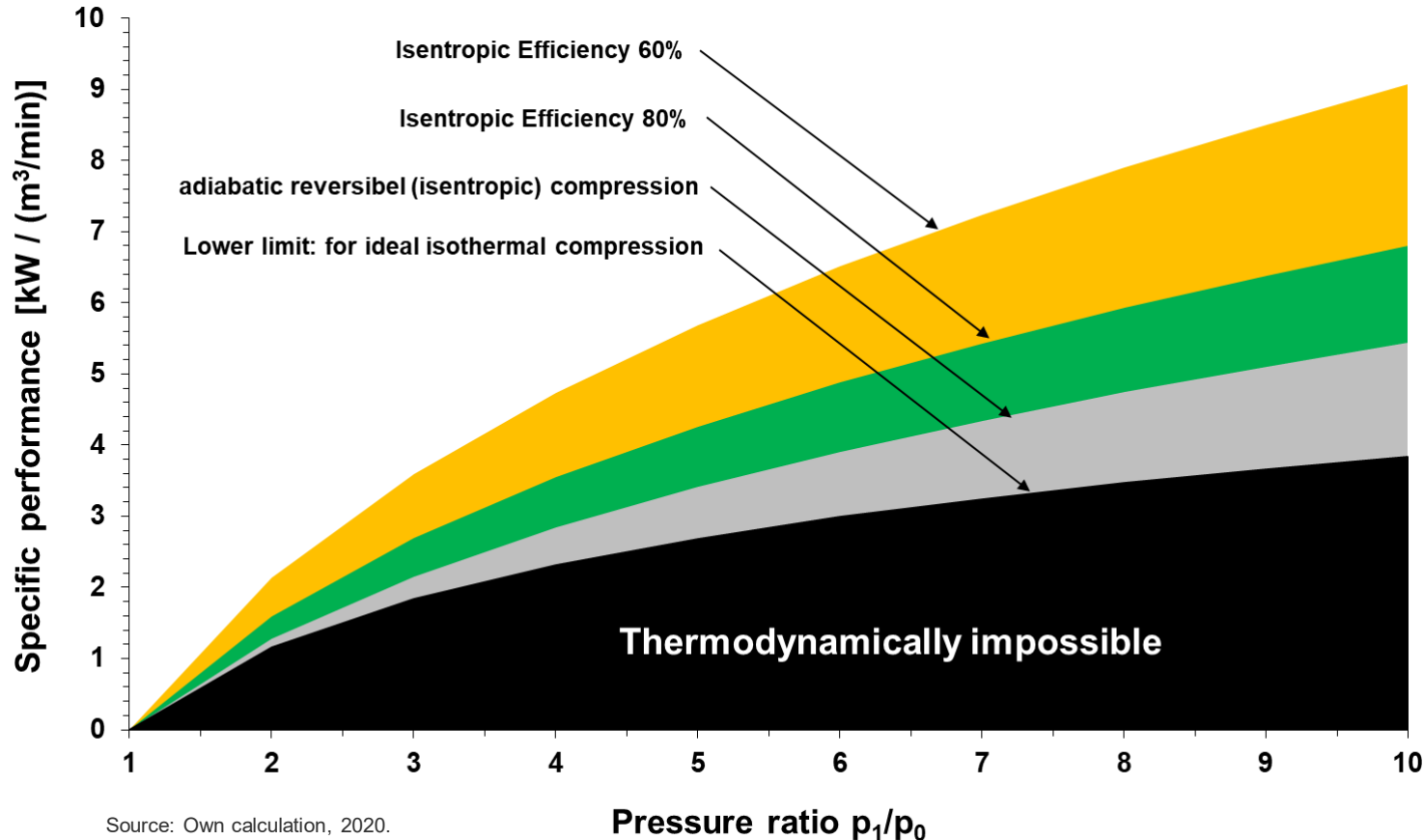
$$\dot{W}_p = p_1 * \dot{V}_1 * \ln\left(\frac{p_2}{p_1}\right)$$

Adiabatic reversible (Isentropic)

$$\dot{W}_p = \frac{\kappa}{\kappa - 1} * p_1 * \dot{V}_1 * \left[\left(\frac{p_2}{p_1}\right)^{\frac{\kappa-1}{\kappa}} - 1 \right]$$

$$\dot{W}_{isothermal} < \dot{W}_{isentropic} < \dot{W}_{real}$$

Isentropic Efficiency and Specific Performance



A specific performance of 6 kW/(m³/min) is equal to a specific energy consumption of 0.1 kWh/m³


Source: Own calculation, 2020.

Isentropic Efficiency

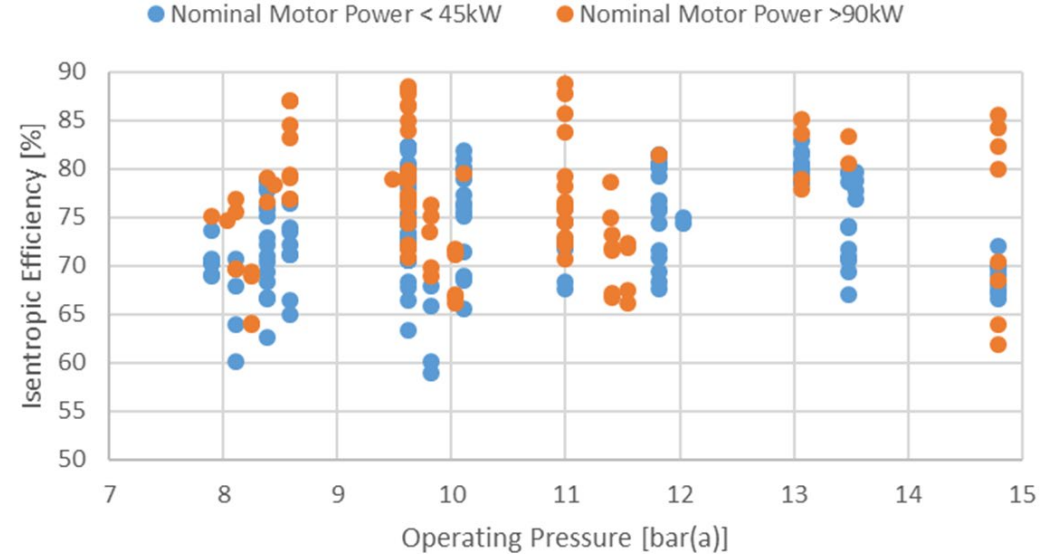
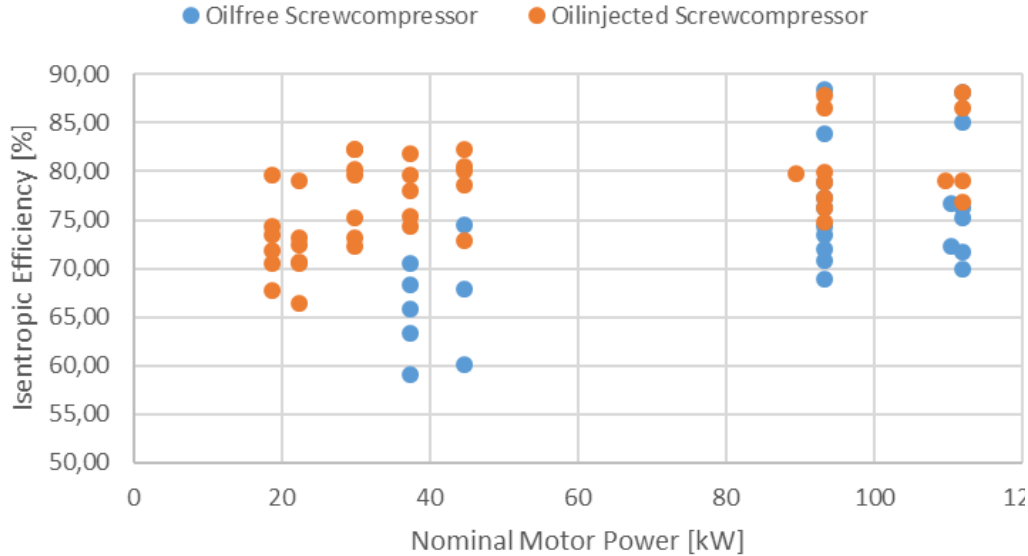
- Dimensionless number, no need for unit conversions
- Clear value range between 0% and 100%
- Efficiencies often used with energy technologies

Specific Power Consumption

- Enables the easy calculation of the energy consumption and costs
- Highlights the importance of pressure reduction and pressure losses in the systems
- Already well established performance indicator

Is it sufficient to specify the isentropic efficiency at a single pressure to select the most efficient air compressor 

Isentropic Efficiency, Compressor Type and Maximum Operating Pressure

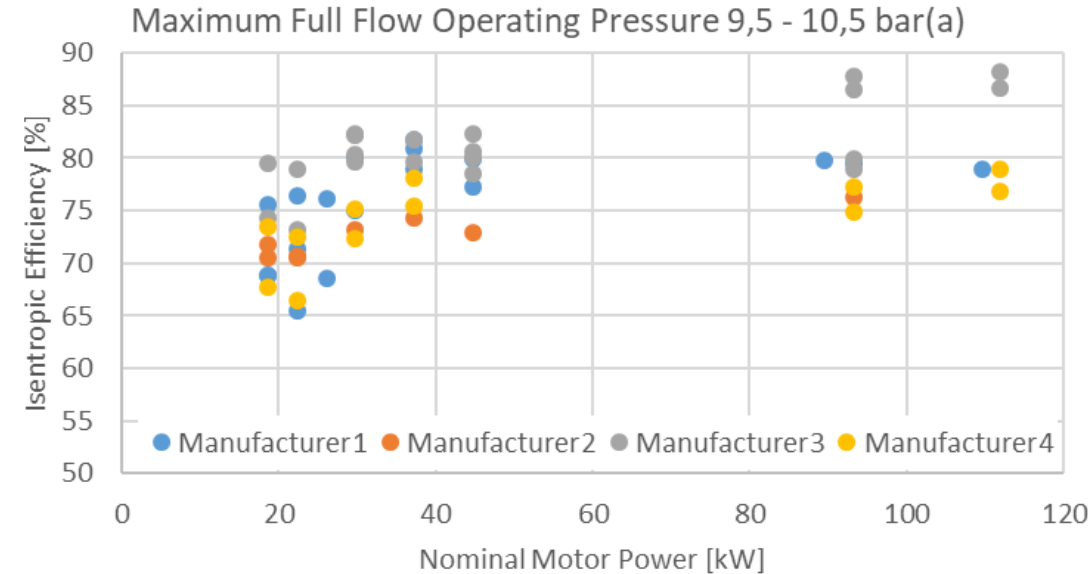
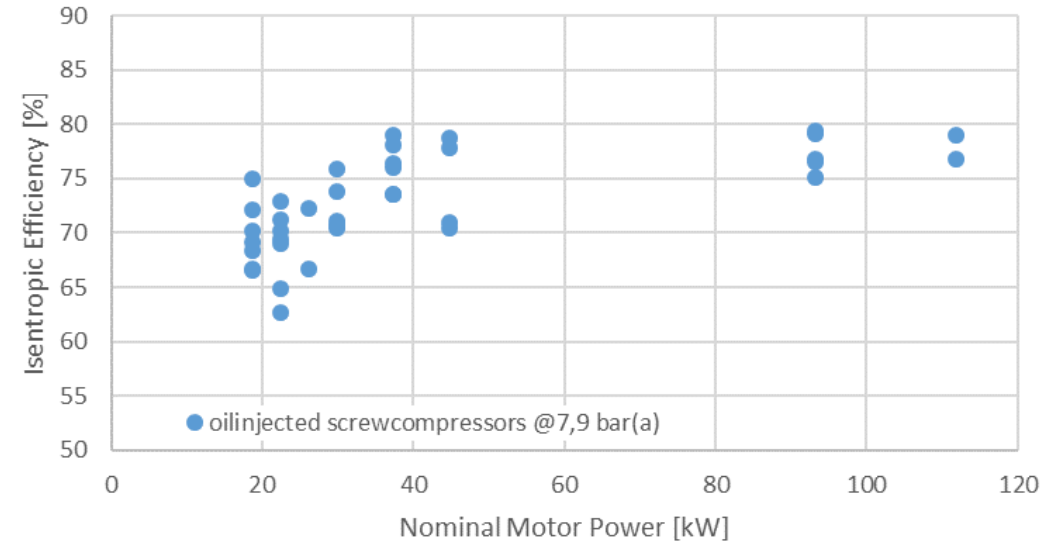


- The lower average compression temperature in oil injected compressors enables higher isentropic efficiencies

- The selection of the air compressor with the highest isentropic efficiency does not guarantee highest isentropic efficiency at the real operating point in the use case

Source: Data CAGI, own graphics, 2020

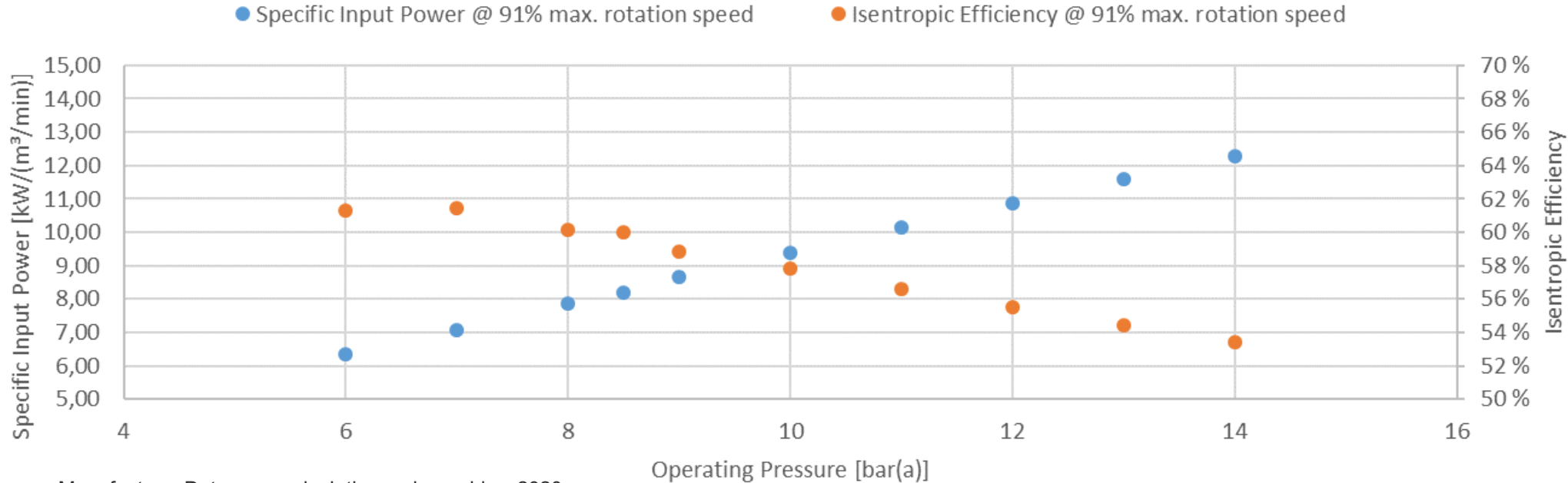
Isentropic efficiency and compressor size



Source: Data CAGI, own graphics, 2020

- the isentropic efficiency of an air compressor is dependent on the compressor size; as larger the compressor the lower the specific losses
- the isentropic efficiency is dependent of the manufacturer of the product

Specific Input Power and Isentropic Efficiency of a VFD Air Compressor at different operating pressures

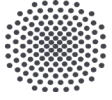


Source: Manufacturer Data, own calculation and graphics, 2020

- the isentropic efficiency of an air compressor typically increases with lower operating pressure
- the small change in isentropic efficiency hides the significant change in the energy consumption

Conclusions and Outlook

- Labelling of air compressor is widely discussed in the context of the Energy Related Products Directive, but neither any labelling requirements nor minimum energy efficiency standards had been implemented.
- In the past the specific performance was used to compare air compressors. For the end user, specific performance is a more useful metric compared to isentropic performance as it can be directly used for the calculation of the energy consumption without any detailed thermodynamic knowledge.
- Manufacturers should be required to publish the full data sheets with all relevant energy performance data of their products
- System aspects are important. Larger compressors having a higher isentropic efficiency but will perform worse compared to a smaller compressor if they can not be utilized at full power.
- Compressed air users should make their purchase decisions based compressor performance at real operating conditions.



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Thank you!



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We are looking forward to meet you all in person
from September 21-23, 2021 at EEMODS 2021 in
Stuttgart, Germany



www.eemods21.org

