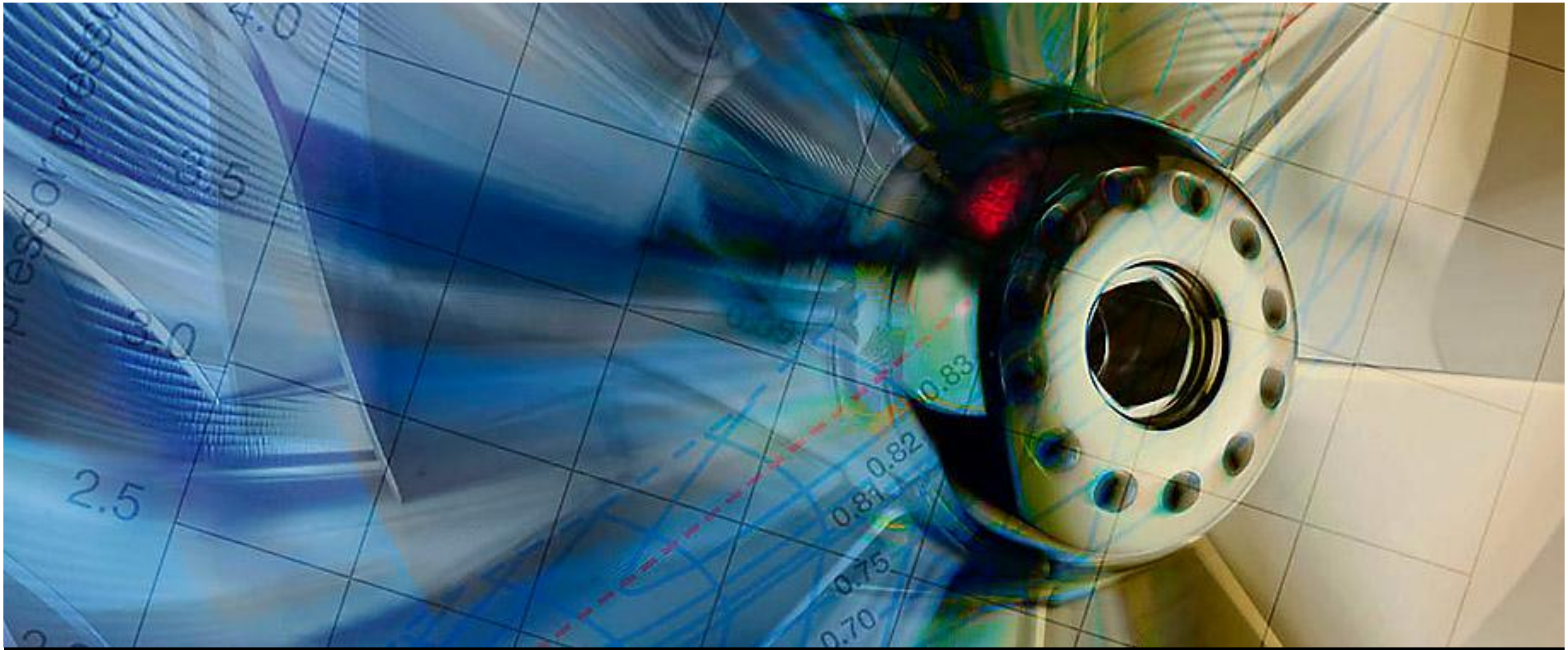
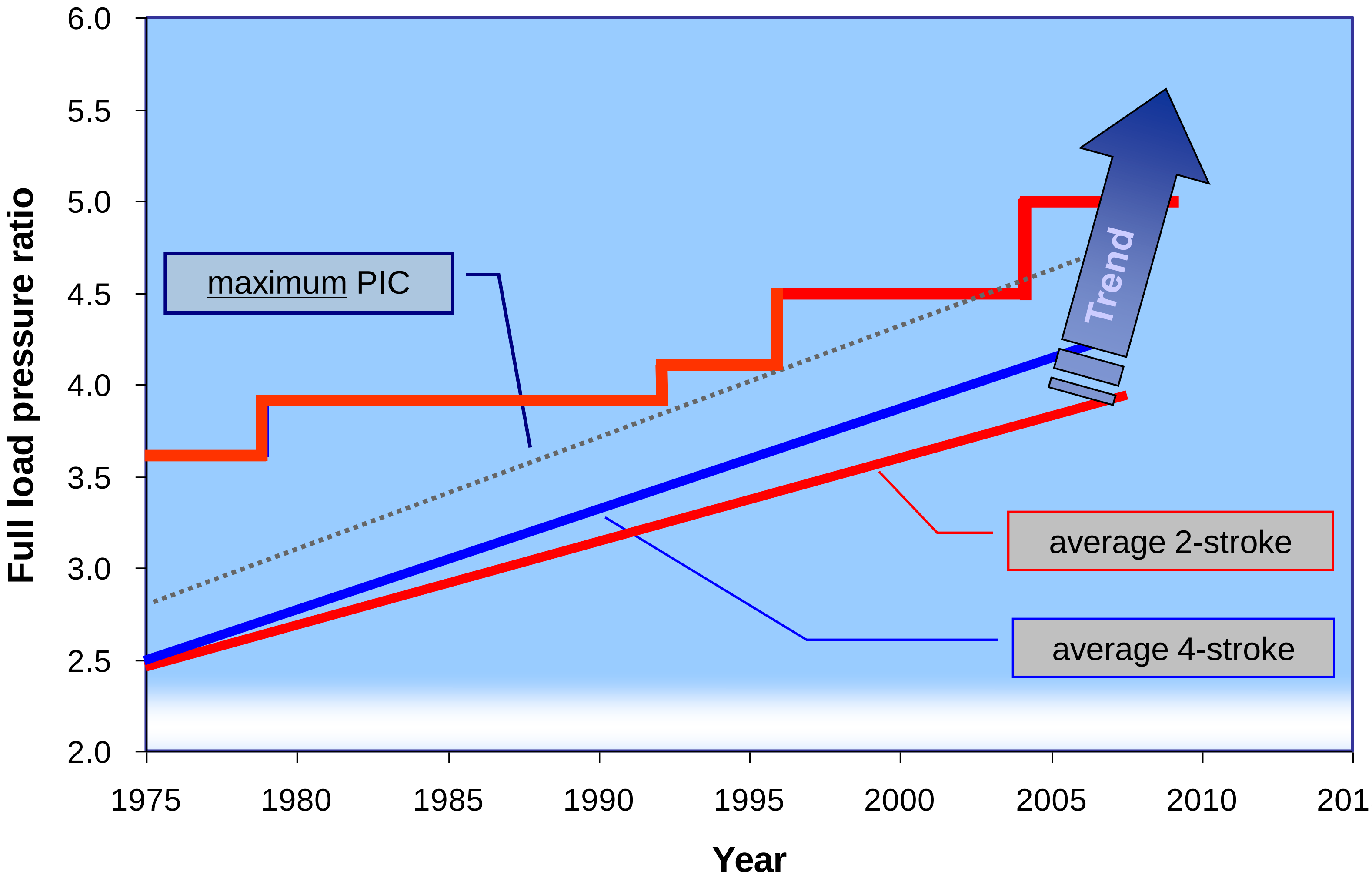


K. Heinrich, ABB Turbo Systems Ltd., 2011-09-27, Ship Efficiency 2011, 3rd International Conference

Advanced Turbo Charging

2-Stage TC's, Exhaust Gas Recirculation and Waste Heat Recovery

Advanced Turbocharging
Introduction



Full load pressure ratio with aluminum compressor wheel / base load application (50'000 rhrs)

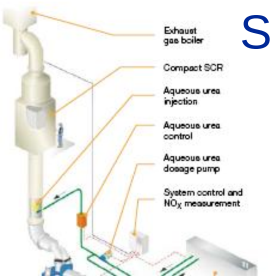
Advanced Turbocharging
Introduction

Key technologies (mid term, IMO III)

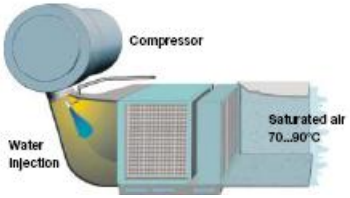
NOx -80%

- Many different methods for NOx reduction, -80% only proven with SCR and gas as fuel
- Can other methods or a combination thereof reach -80% better or at a lower cost than SCR?

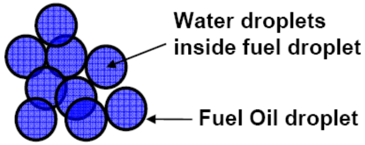
SCR



Humid air

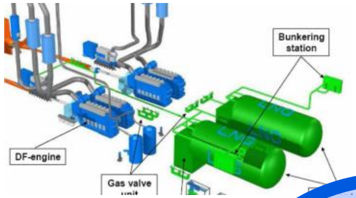


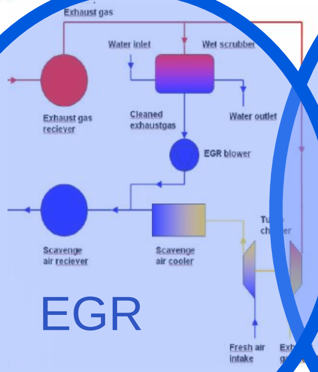
Emulsion



Water injection

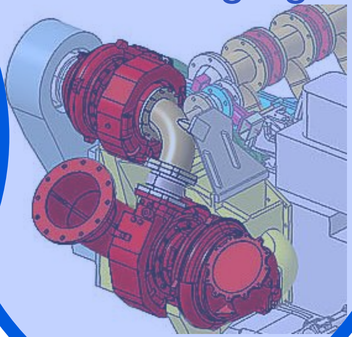
Gas / dual fuel





EGR

2-stage turbocharging

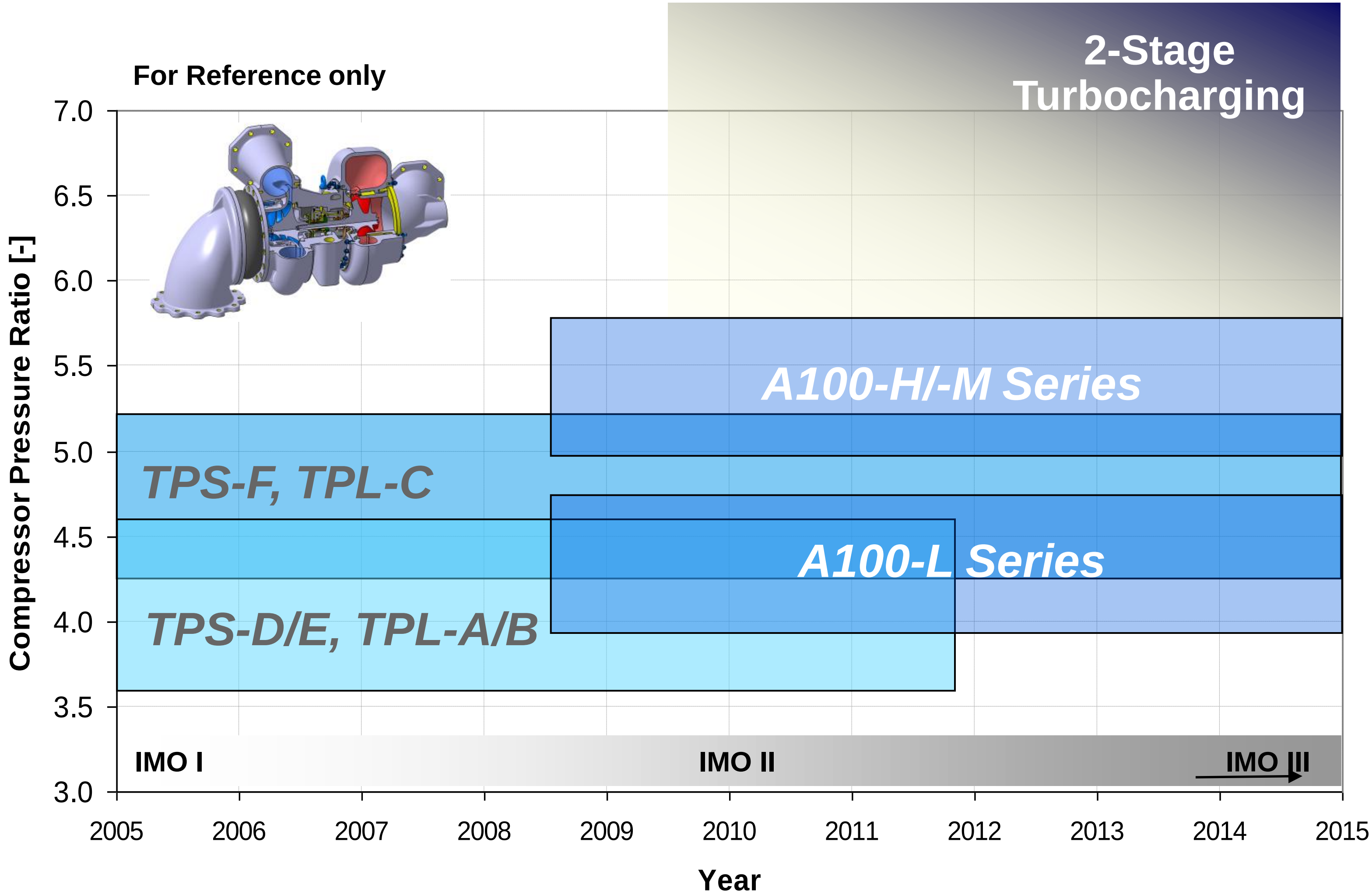


VVT

Common rail

ABB

Advanced Turbocharging
Introduction



Remark: Pressure ratio without margins – ca. 0.2 bar for most applications

ABB

Advanced Turbocharging
Outline

- 2-stage Turbocharging
  - Boundary conditions
  - Special Requirements for High Pressure TC's
  - ABB Product Development
- Exhaust Gas Recirculation
  - Challenges
  - Possible solutions
- Waste Heat Recovery
  - Reasons for WHR
  - Potential
  - ABB Offerings

Advanced Turbocharging
Outline

- **2-stage Turbocharging**
  - **Boundary conditions**
  - **Special Requirements for High Pressure TC's**
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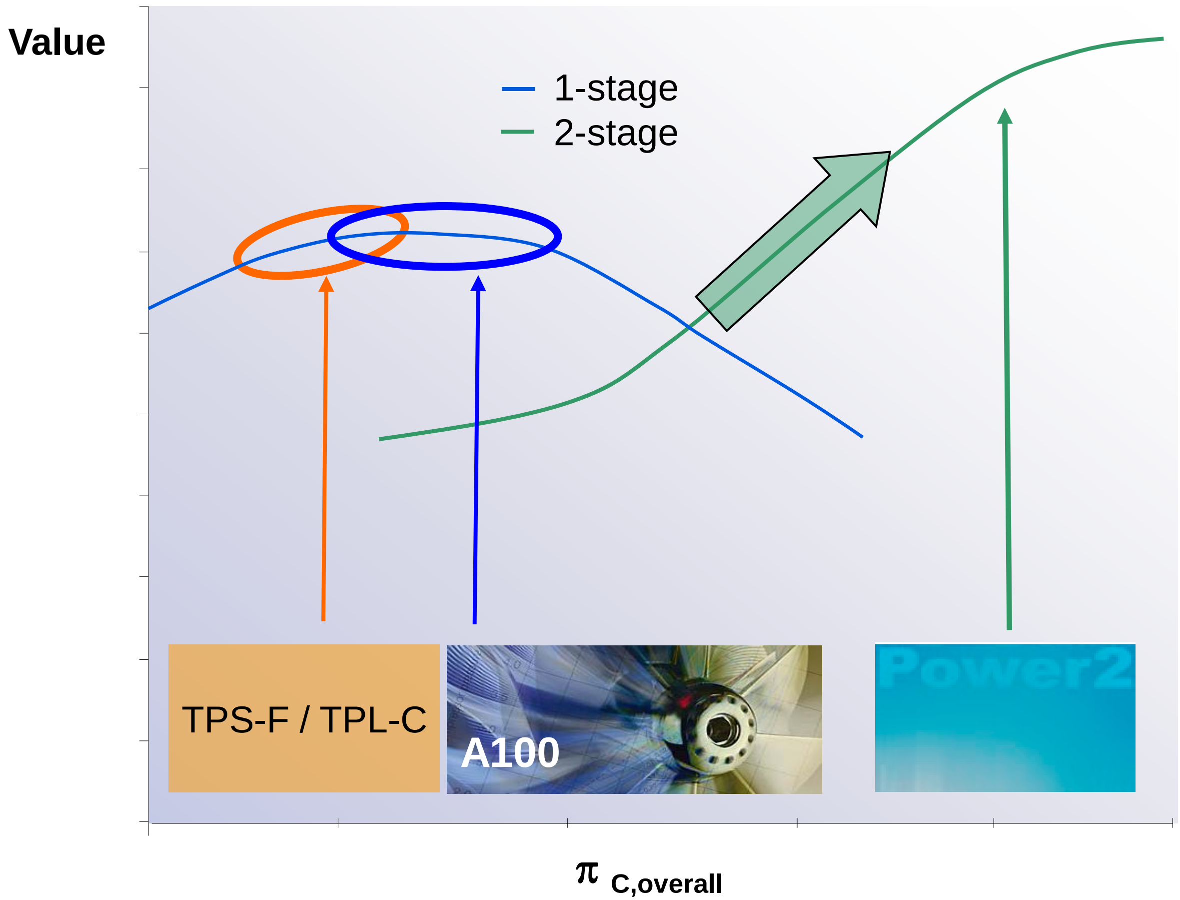
Advanced Turbocharging
2-stage Turbocharging



1-stage π_{sC} > 5.0

- Part load becomes challanging
- TL-Frame size as known
- TL-Matching needs more variants– Product portfolio more complex

2-stage π_{sC} > 6.5

- Smaller frame sizes
- Higher η_{TC}
- More flexibility for matching
- More flexibility for valve timing necessary

Advanced Turbocharging
2-stage Turbocharging

For higher receiver pressure the step to 2-stage charging is necessary

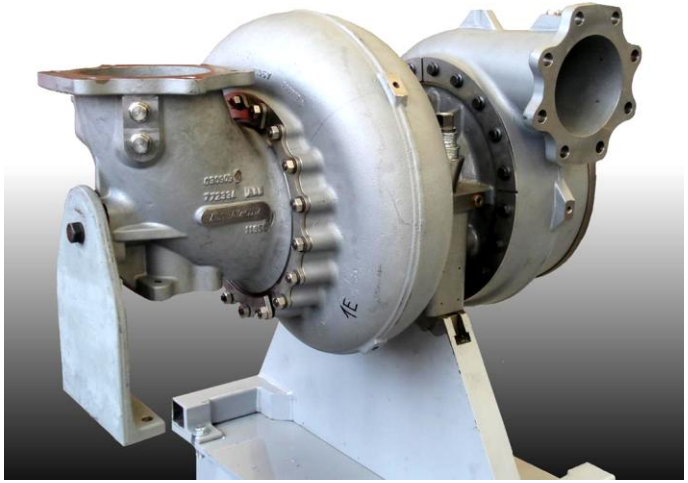
- Charging efficiency up to75%
- Compressor pressure ratio up to 10 ÷ 12 expected
- Higher $\Delta p_{Cyl.}$ over cylinder

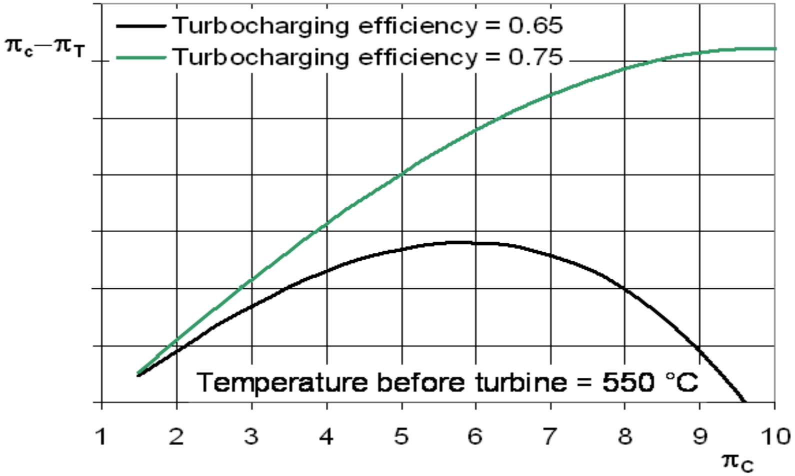
⇨ Use of full potential of Miller cycle possible

⇨ Increased power density of the engine

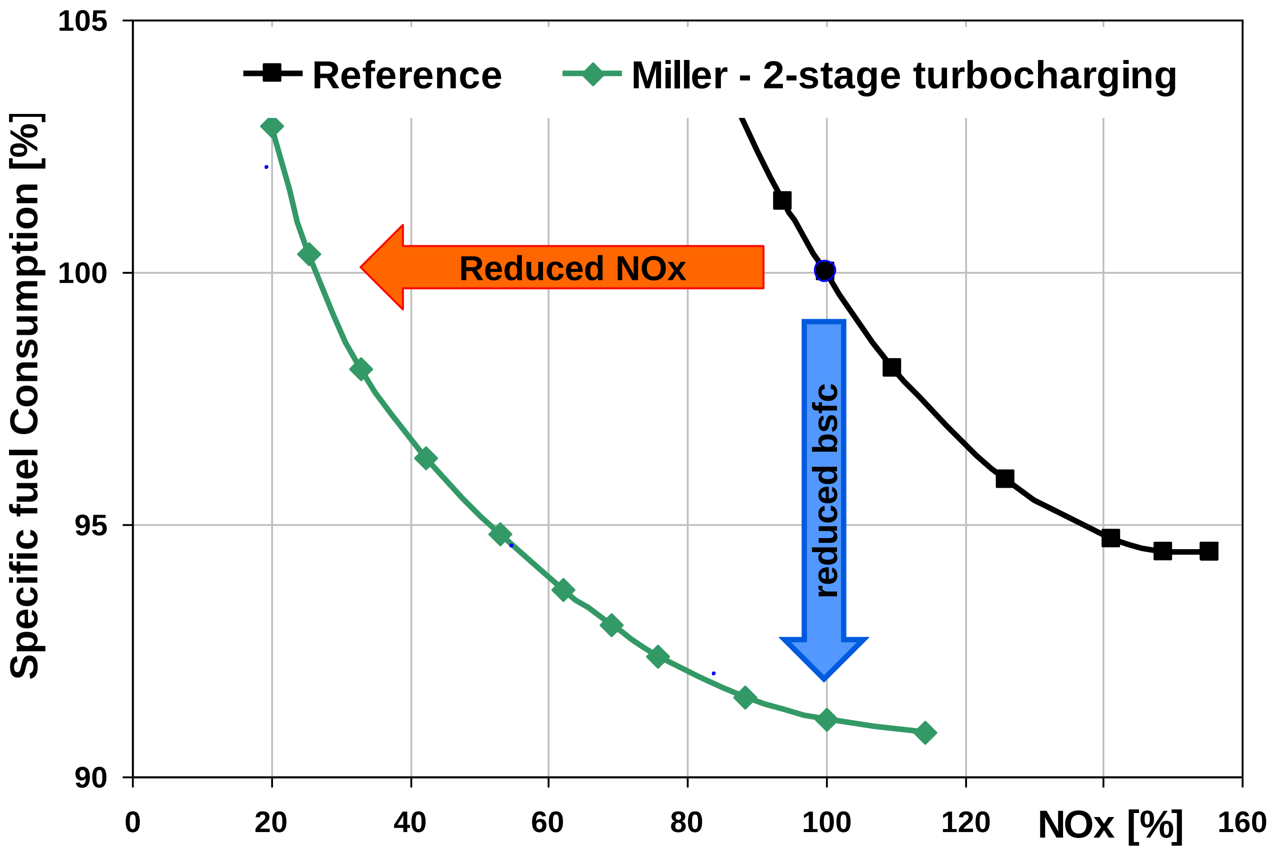
⇨ Use of higher $\Delta p_{Cyl.}$ to reduce valve overlap

⇨ Higher charge air pressure can be used for either NOx or bsfc reduction





Advanced Turbocharging
2-stage Turbocharging

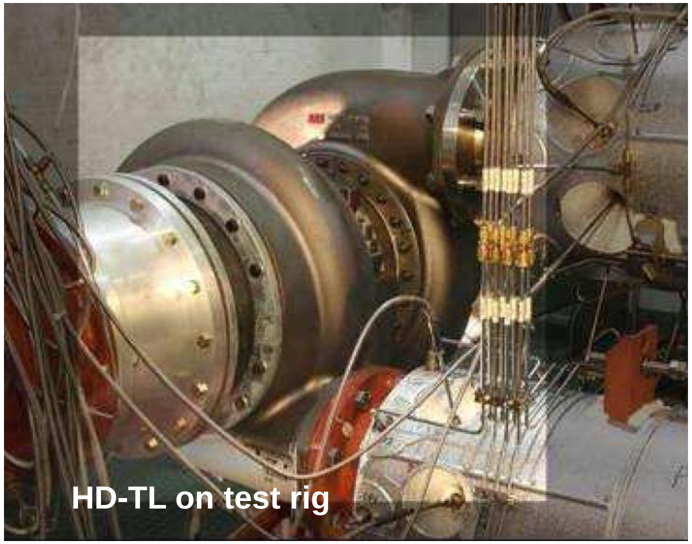


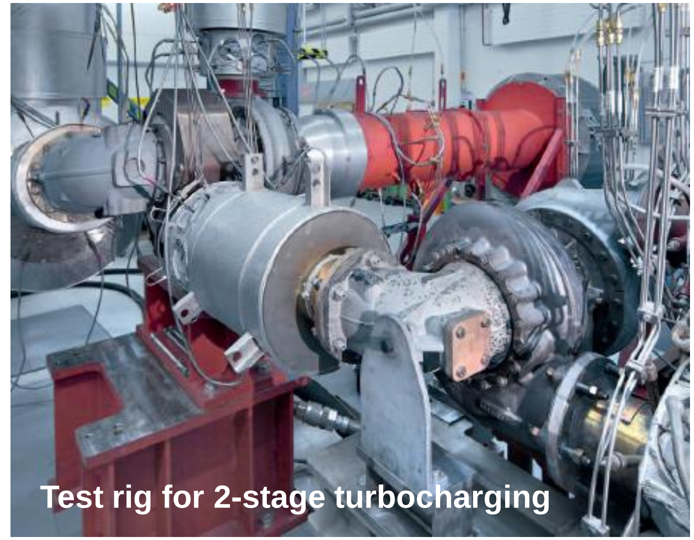
Advanced Turbocharging
2-stage Turbocharging

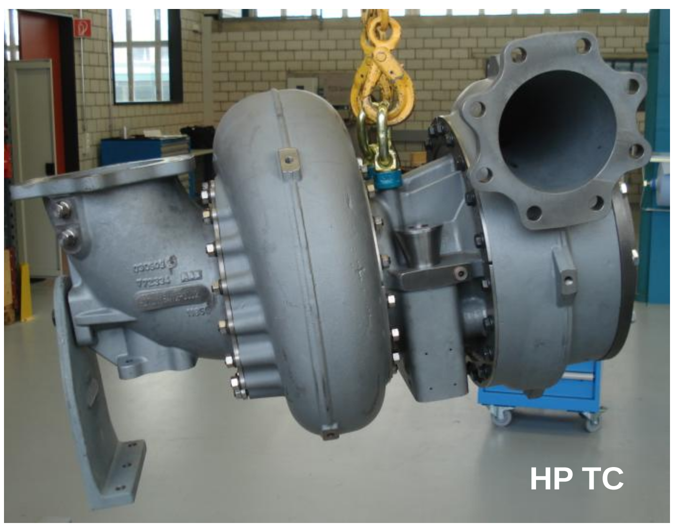
Requirements for a high pressure TC significant differ from standard TC, new design is necessary

- Higher pressure at TC flanges
  - higher forces ➢ new mounting concept
    ➢ new casing and flange design
- Higher air density at compressor inlet
  - Higher shaft torque➢ appropriate design necessary
  - Higher axial thrust and thicker shaft ➢ new bearings needed
- Higher pressure after compressor / before Turbine
  - Shaft sealing must be adjusted to have control over blow-by
- Changed requirements for thermodynamically components
  - Compressor: Efficiency and swallowing capacity higher rated as total pressure ratio, wide maps important
  - Turbine: High flow capacity needed
  - Turbine casing must be redesigned as kinetic energy at turbine outlet is not a loss anymore – energy is available to LP turbine

Advanced Turbocharging
2-stage Turbocharging


HD-TL on test rig


Test rig for 2-stage turbocharging


HP TC


HP TC

Advanced Turbocharging
2-stage Turbocharging

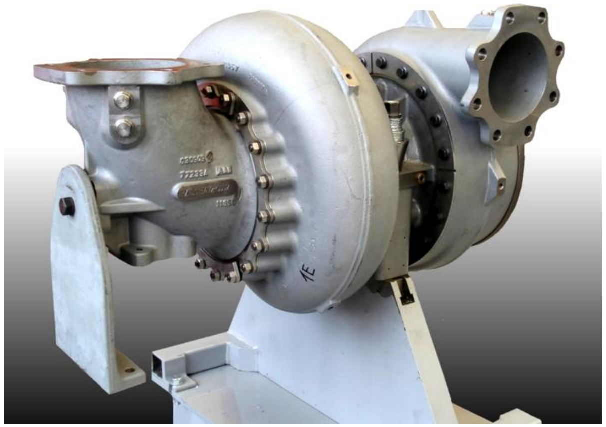
ABB product strategy

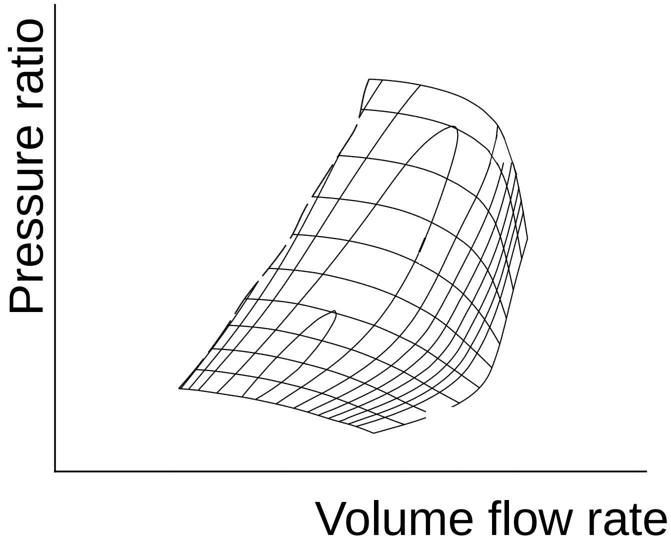
Low pressure turbocharger

- 1st generation derived from existing turbocharger types with partly newly developed thermodynamic components
- Product development for 2nd generation LP TC's ongoing

High pressure turbocharger

- 1st generation radial design finalized
- First 2 radial frame sizes released for sales
- Product development for 2nd generation axial and radial HP TC's ongoing





ABB

Advanced Turbocharging
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- 2-stage Turbocharging
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- **Exhaust Gas Recirculation**
  - **Challenges**
  - **Possible solutions**
- Waste Heat Recovery
  - Reasons for WHR
  - Potential
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Advanced Turbocharging
Exhaust Gas Recirculation

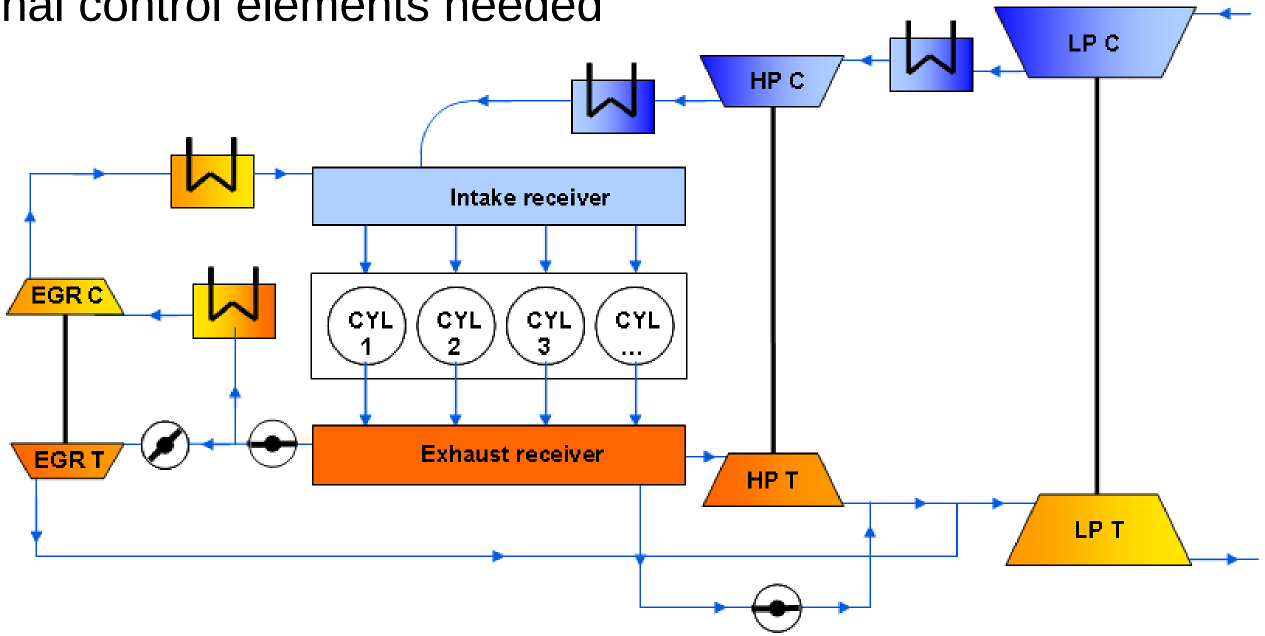
Why EGR:

- EGR is one method to reduce the NOx level
- Technology known from automotive engines
- All components needed for NOx reduction mounted to the engine – no additional space needed
- No additional media needed (e.g. urea)
- HP EGR is thermodynamically more efficient compared to low pressure EGR
- With HP EGR the main compressors are protected from the exhaust gases
- Possible solutions: EGR blower with electric motor or EGR turbocharger

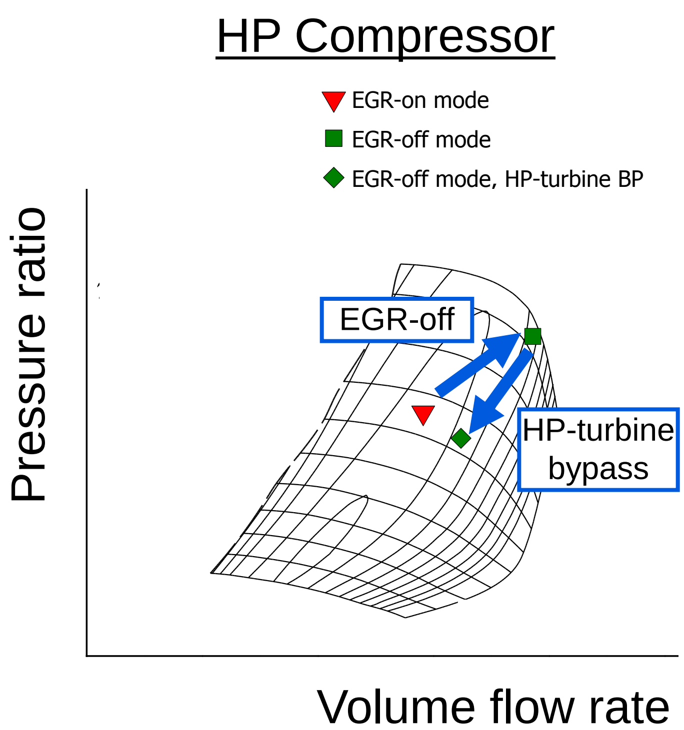
Advanced Turbocharging
Exhaust Gas Recirculation

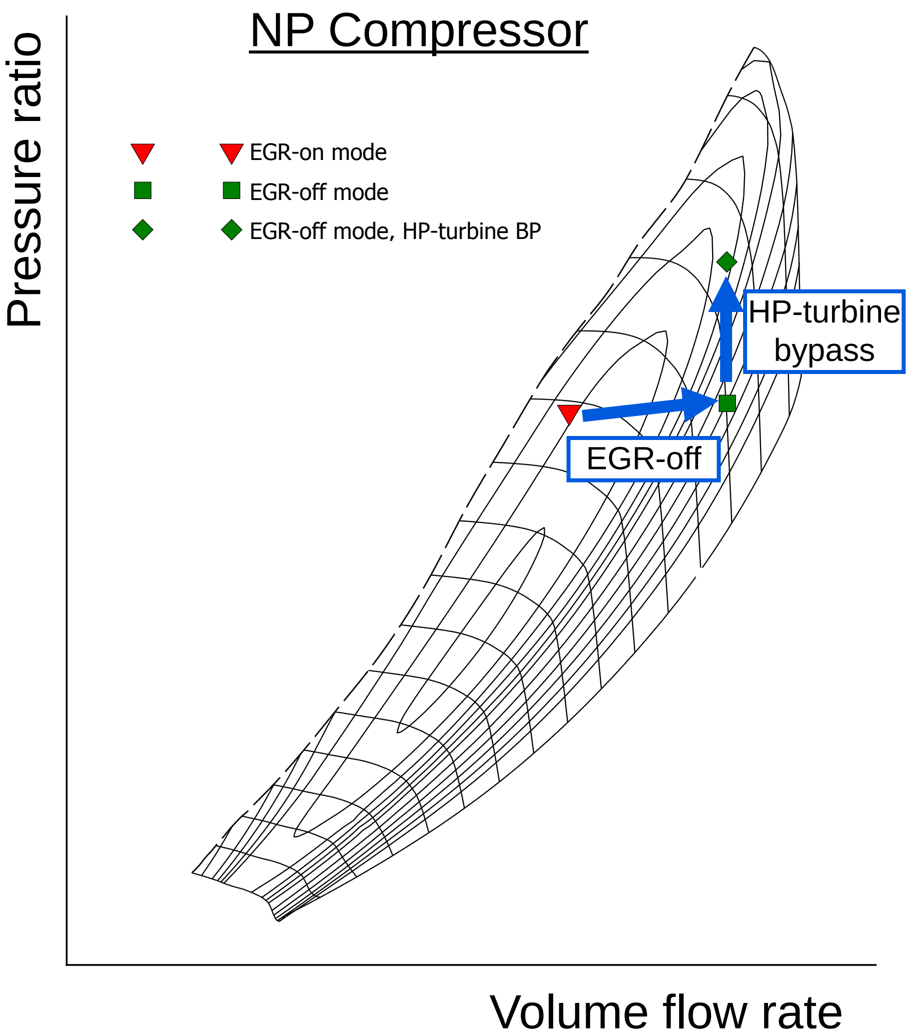
Challenges:

- Fuel Quality – EGR not feasible with HFO
- Switch in between ECA and non-ECA (EGR on vs. EGR off mode)
- Reliability of EGR compressor
- Additional cooler capacity needed
- Additional control elements needed



Advanced Turbocharging
Exhaust Gas Recirculation





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  - **Reasons for WHR**
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Waste Heat Recovery

Reasons to apply Waste Heat Recovery WHR

- Increasing fuel prices
- Reduction in total fuel consumption
- Reduction in exhaust emission
  - CO_2
  - NOx
  - SOx
  - Particulars
- "Green Vessel" → Competitive advantage

Advanced Turbocharging
Waste Heat Recovery

- **Gas**

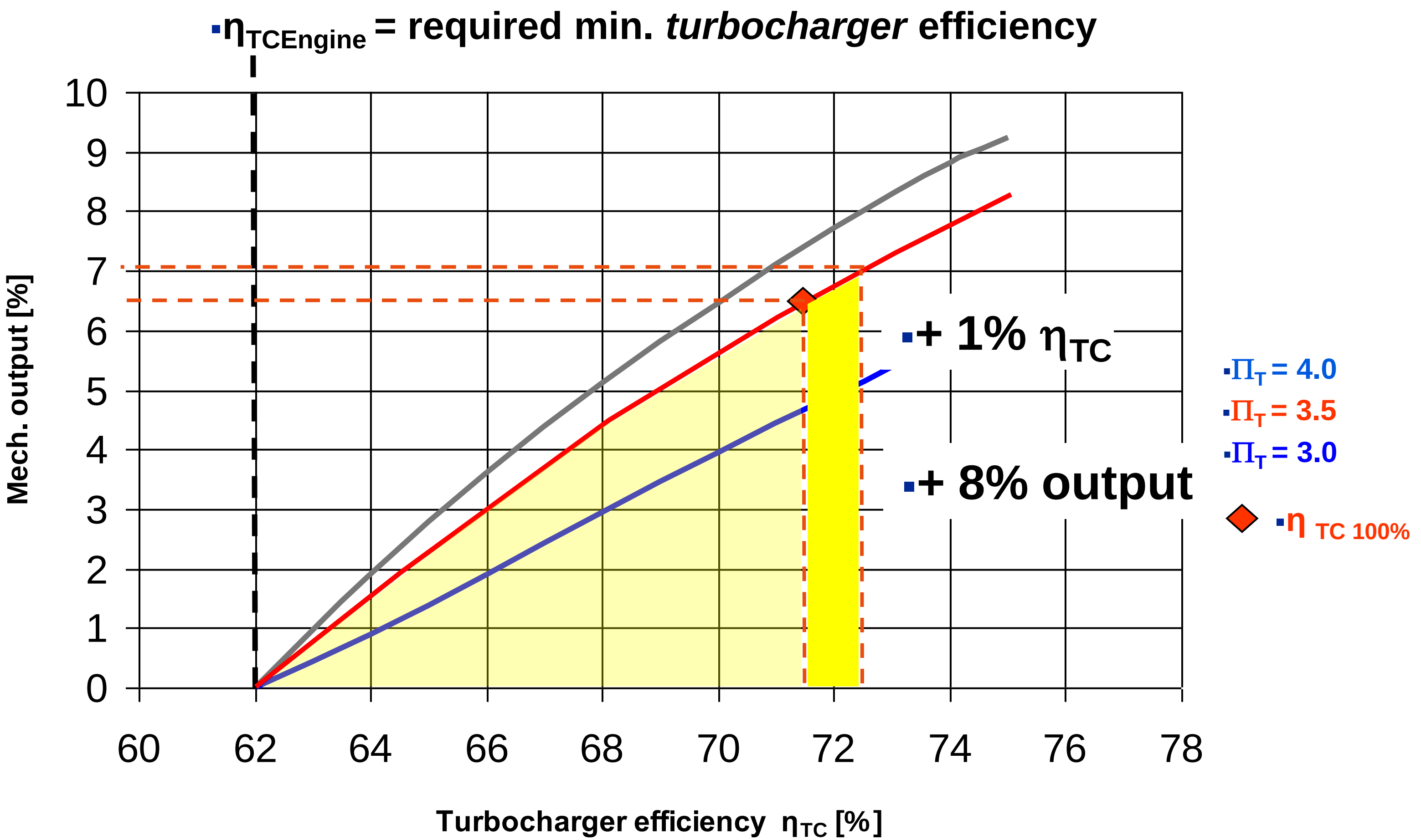
  - Power turbine → Generator
  - Shaft motor or without shaft motor

- **Steam & Gas**

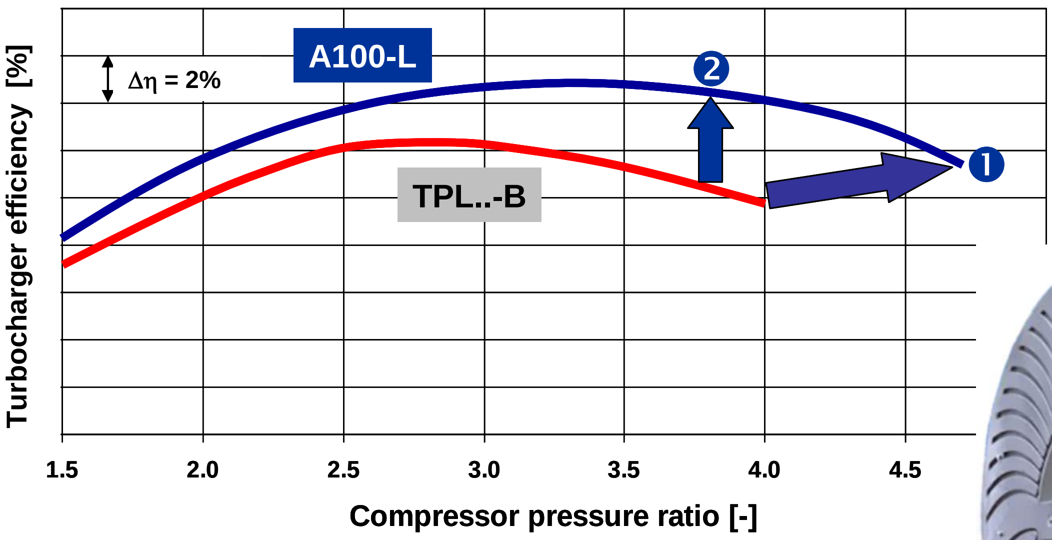
  - Waste heat boiler
  - Steam turbine
  - Power turbine & steam turbine → Generator
  - Shaft motor

ABB

Advanced Turbocharging
Waste Heat Recovery



Advanced Turbocharging
Waste Heat Recovery



A100-L

❶ Power increase by about 20% or NO_x reduction ("2-stroke Miller")

❷ Reduction of fuel consumption (with power turbine)

Advanced Turbocharging
Waste Heat Recovery

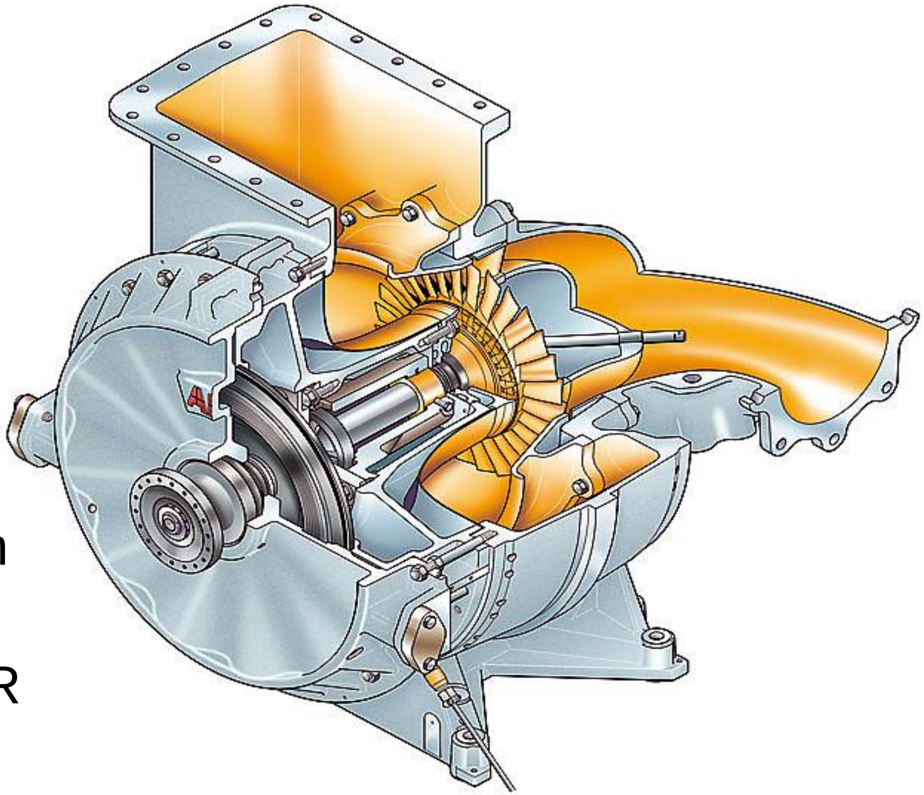
PTL1700

- 800…1700kW
  mech. output

PTL3200

- 1500….3200kW
  mech. output

Power turbine in combination with high efficiency A100-L offers good potential for WHR



Advanced Turbocharging
Conclusion

- Driven by increasing engine power density, call for reduced specific fuel oil consumption and tighter emission regulations a strong trend for higher charge air pressure can be seen
- Several technologies for emission reduction are under investigation. Many of them call for adjusted charging systems
- To meet the market requirements ABB develops it product portfolio accordingly
- First two stage turbocharging systems are introduced to the market already. The product range will be expanded as needed.
- ABB supports emission reduction technologies by adjusted charging systems
- Performance of actual A100-L turbo chargers has excellent potential to apply waste heat recovery systems

Power and productivity
for a better world™

ABB