Thermodynamic Challenges in Combustion Development and Turbocharging of High BMEP Medium Speed Gas Engines

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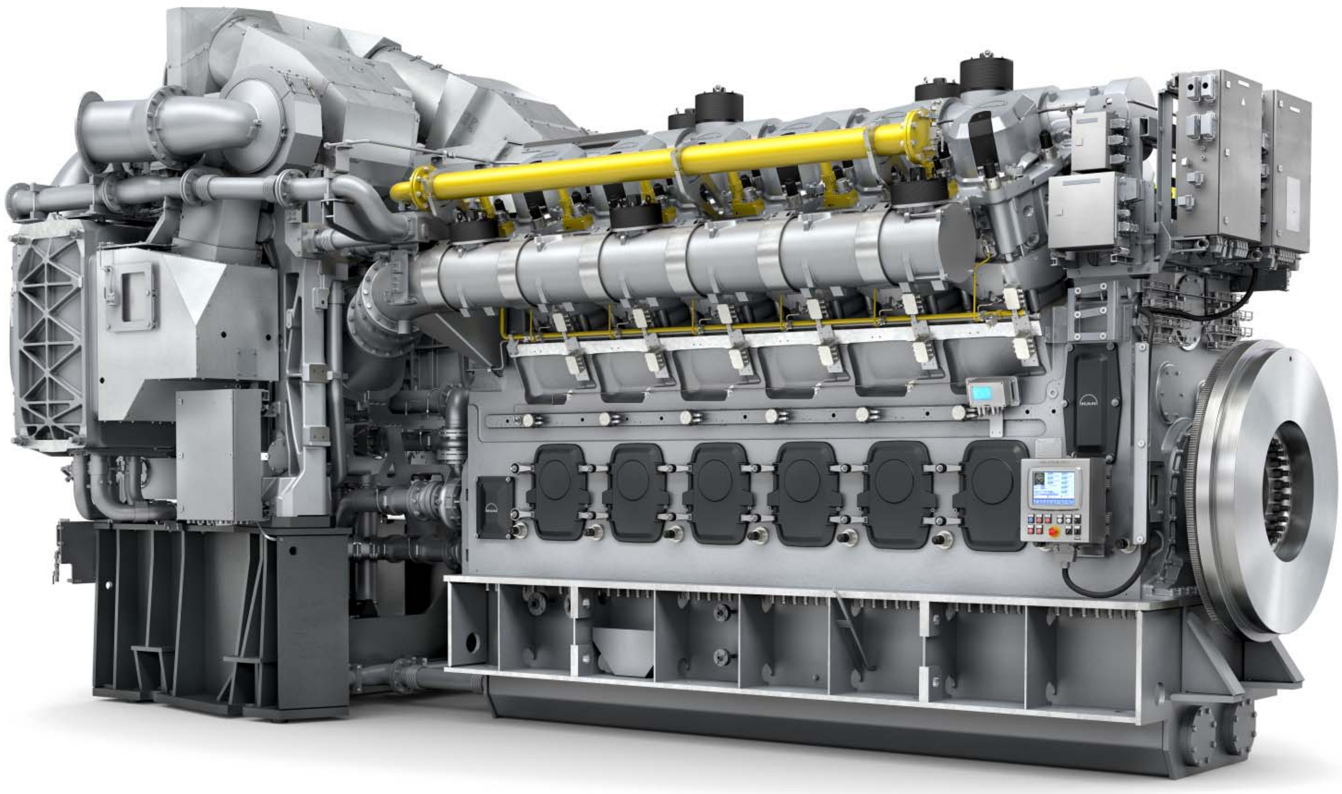
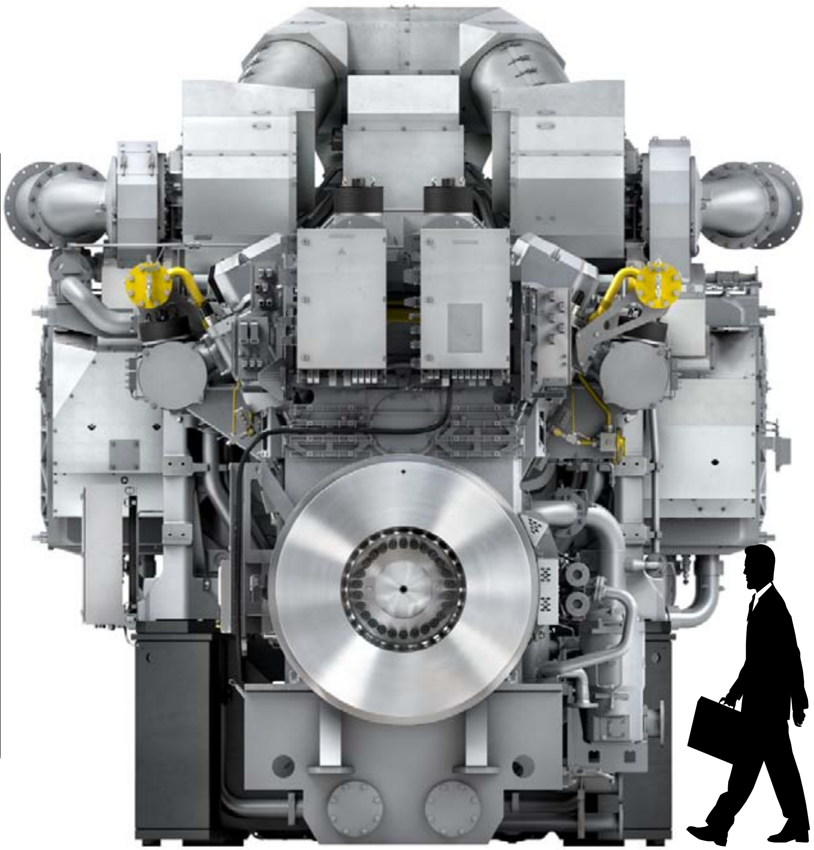


Leading Example: The New V35/44G TS

Main Technical Data

Specification	Dimension	50 Hz		60 Hz	
Bore / Stroke	mm	350 / 440			
Swept volume	liter/cyl.	42.3			
V-Angle	°	55			
Speed	min^{-1}	750		720	
Power	kW_m/cyl.	620		590	
BMEP	bar	23.4			
Engine power	kW_m	*12V*	*20V*	*12V*	*20V*
		7,440	12,400	7,080	11,800
Emissions		Acc. to TA-Luft			

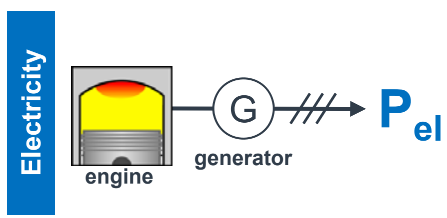


Leading Example: The New V35/44G TS

Main Technical Data

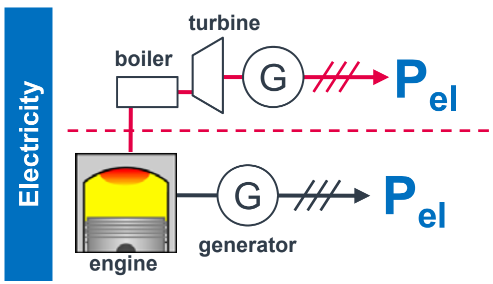
Applications

Single Cycle (SC)



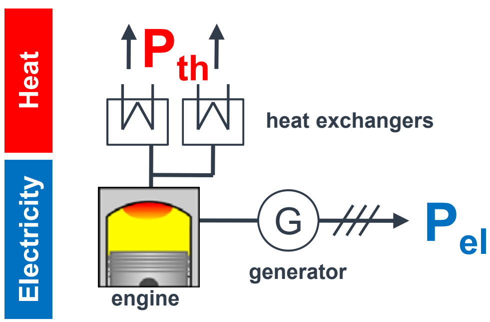
- Electrical power generation
- Focus: Maximum engine efficiency

Combined Cycle (CC)



- Electrical power generation with engine and steam bottoming cycle
- High exhaust gas temperature favorable
- Goal: Maximize total system efficiency
- Drawbacks in engine efficiency can be beneficial for total efficiency

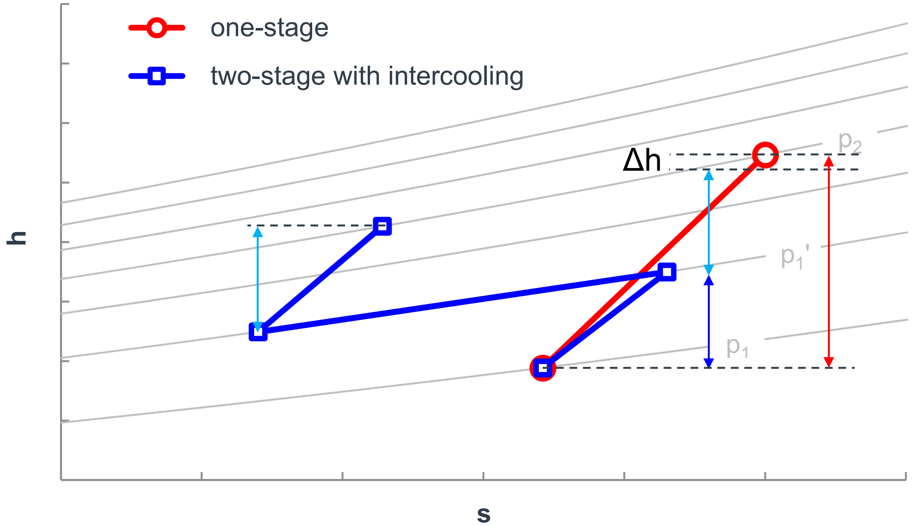
Combined Heat and Power (CHP)

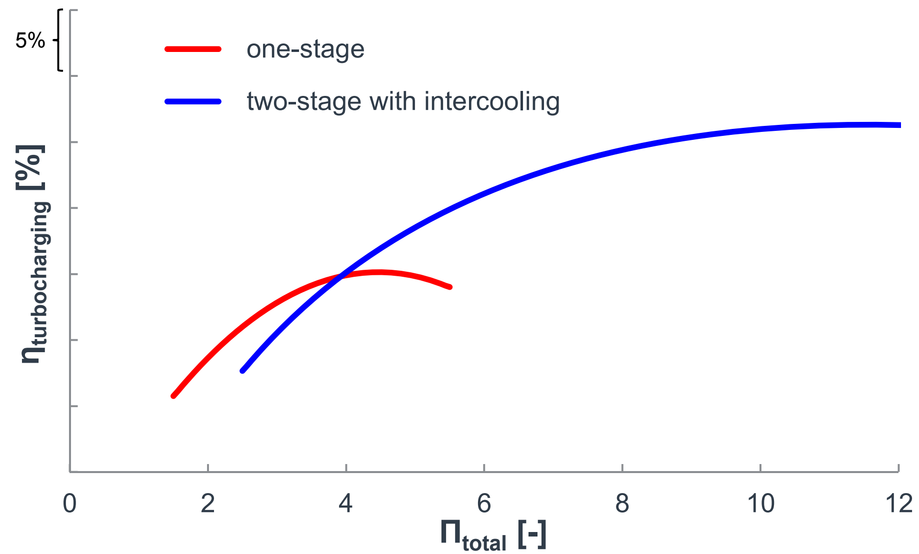


- Electrical power generation
- Heat generation, e.g. for district heating networks
- Utilization of all engine heats: oil, water, charge air, exhaust gas
- Optimization towards highest total efficiency or highest total earnings

Motivation for Two-stage Turbocharging

Reduction of Compression Work

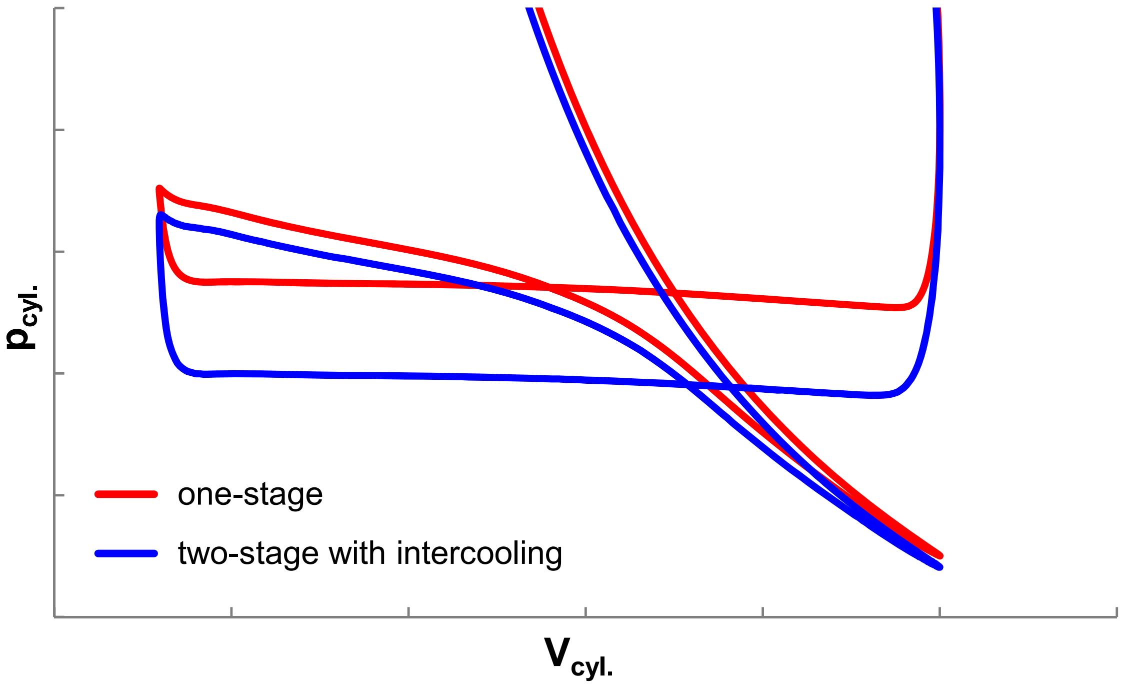




- Reduction of compression work via two-stage compression with intercooling, approximation to ideal isothermic compression
- Higher pressure ratios achievable
- Enables enhanced Miller valve timings

Motivation for Two-stage Turbocharging

Positive Effect on Pumping Work



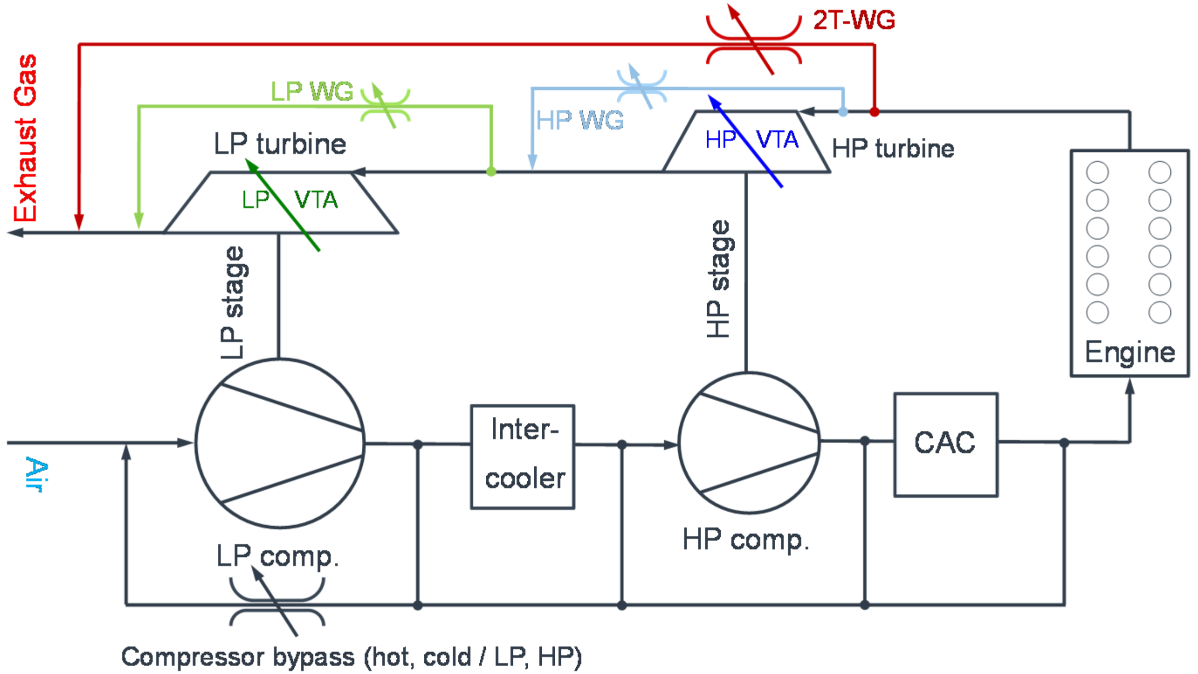
Boundary conditions

- Constant air-fuel ratio
- Constant valve timings

- Increase of scavenging pressure and gain from pumping loop
- Lowering of knock tendency due to better scavenging effect

Motivation for Two-stage Turbocharging

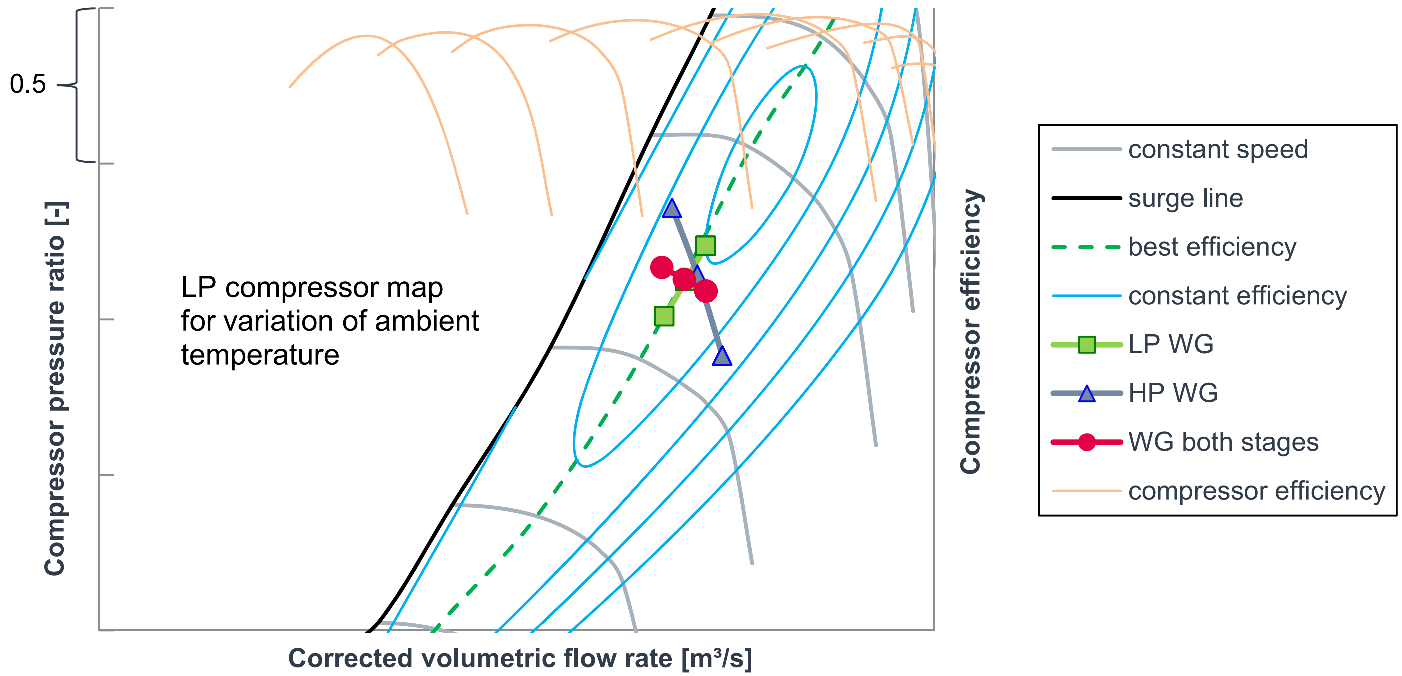
Choice of Best Charge Air Pressure Control Strategy



- Choice of optimal charge air pressure control device and strategy leads to further increase in turbocharging efficiency and even wider operating range regarding ambient pressures and temperatures
- Factors to consider: efficiency, compressor/turbine sizes, operation within compressor maps, VTA operational range

Motivation for Two-stage Turbocharging

Choice of Best Charge Air Pressure Control Strategy



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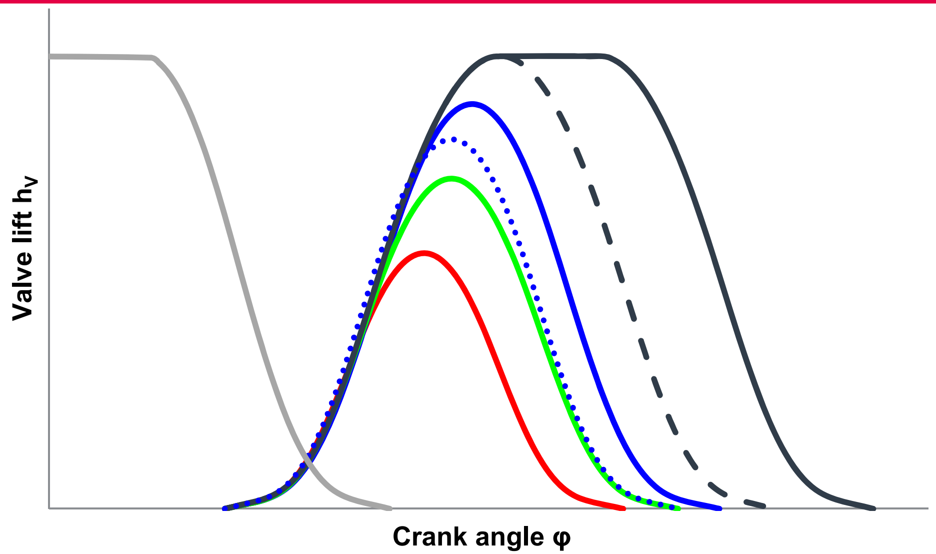
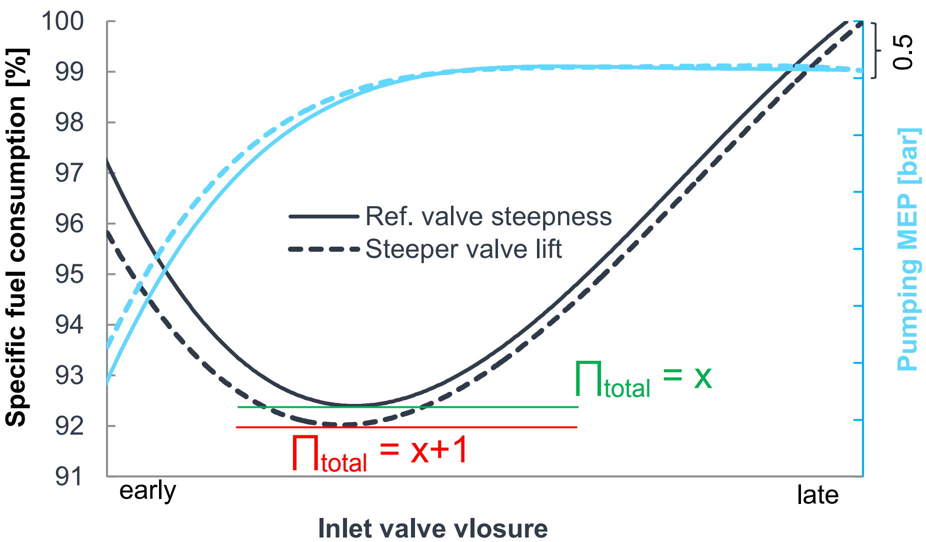
Two-stage turbocharging as a key technology for higher BMEP and efficiency

Miller Valve Timing

Influence of Max. Valve Acceleration





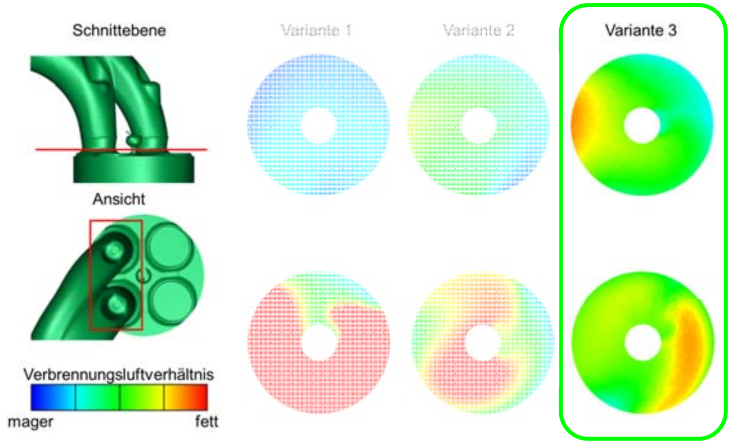
Influence factors on optimal Miller valve timing:

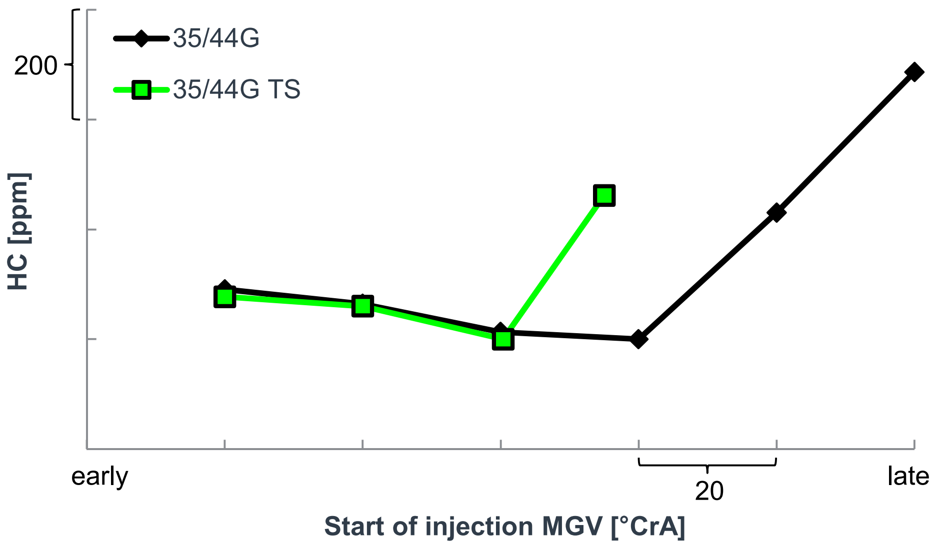
- Turbocharging efficiency and pressure ratio→ utilization of two-stage turbocharging with intercooling
- Optimization of valve train with respect to mechanical boundary conditions, e.g. max. acceleration while sustaining cam-valve-contact, max. Hertzian stress
- Pumping loop losses because of lowered valve lift (constant acceleration) → optimization of valve train minimizes these losses
- Increased engine compression ratio → efficiency high pressure cycle

Goal: Find optimum between pumping losses and gain from high pressure cycle

Optimization of Gas Admission

Minimization of Fuel Consumption and HC Emissions



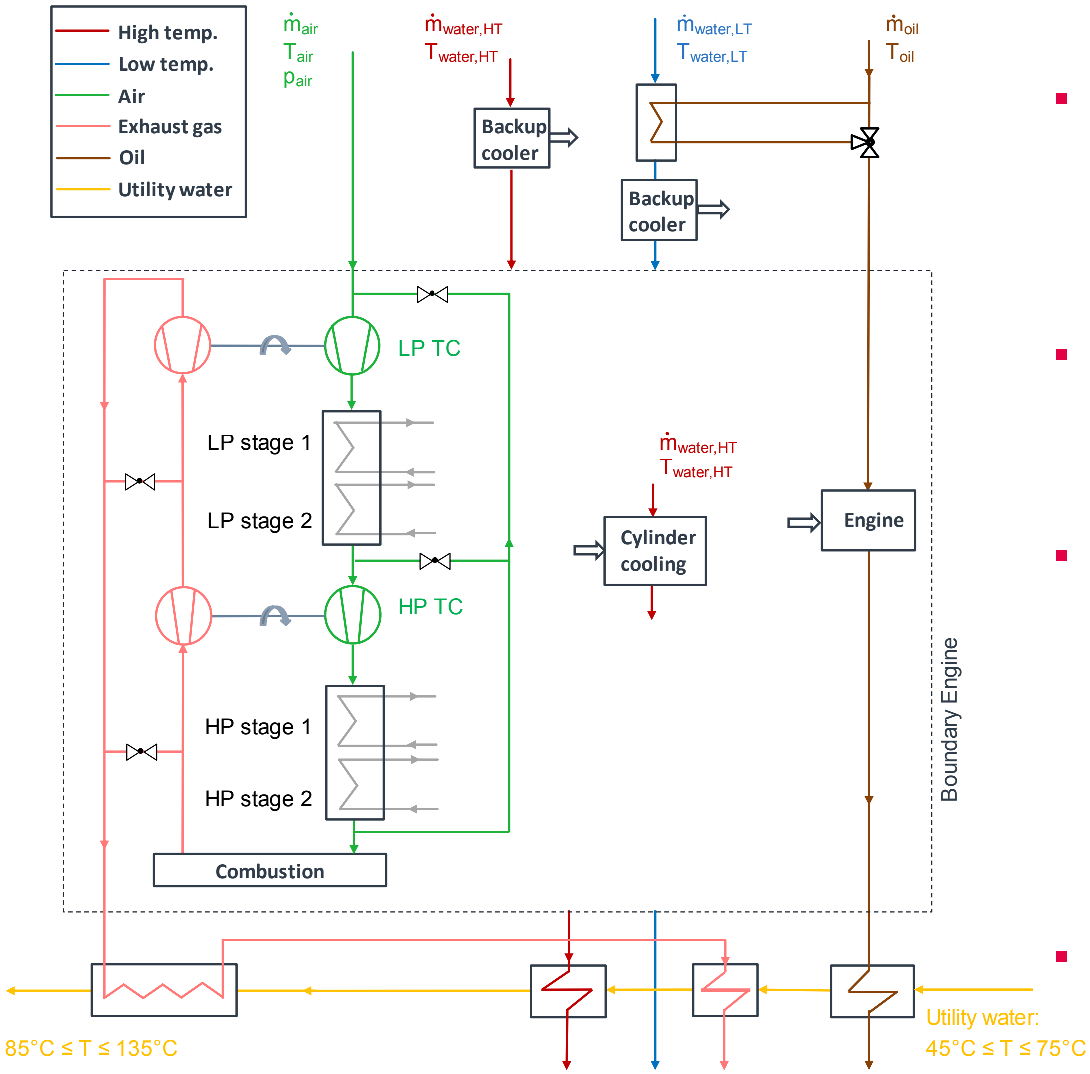


- Optimization of gas admission pipes via 3D-CFD and single cylinder tests on 35/44G (one-stage)
- Configuration for best possible mixture homogeneity adopted for 35/44G TS
- Shorter inlet valve opening phase and higher cylinder power combined with more Miller requires adjustment of gas admission timing
- Earlier gas admission reduces fuel consumption and hydrocarbon emissions

Power increase shrinks the available window for perfect gas admission

Top of the Line Efficiency with CHP

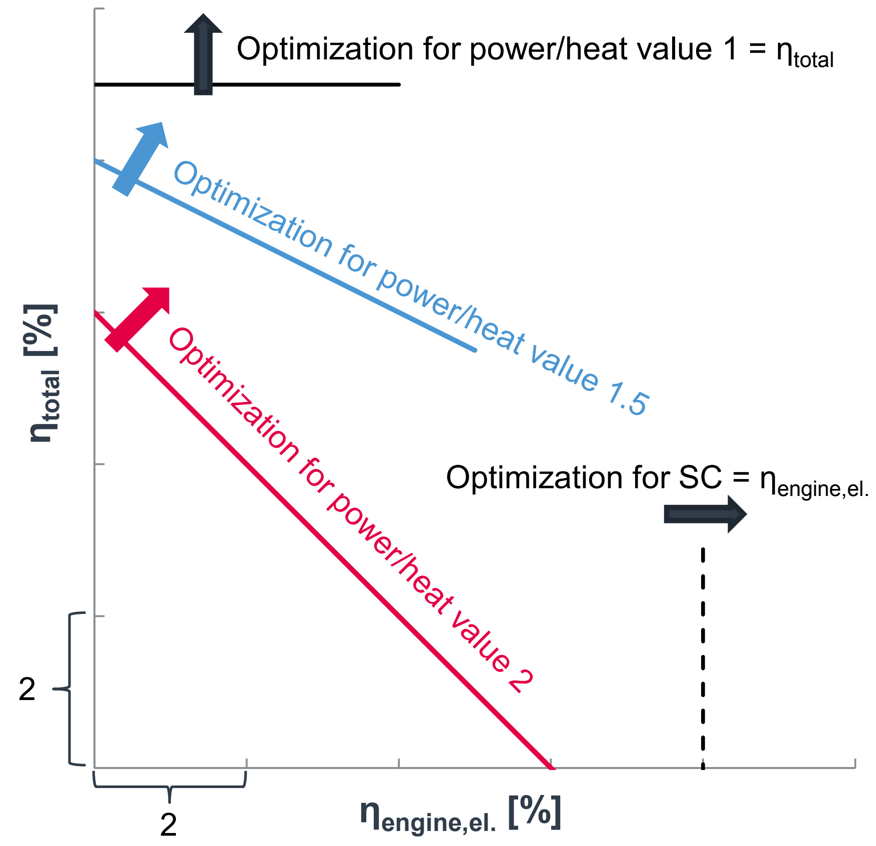
Optimization of Cooling System Layout



- Pre-Layout of cooling concept:
  - High degree of freedom due to 2 charge air coolers with 2 stages each (derived from SC engine)
- Pre-layout of engine configuration (compression ratio fit for high charge air temperatures)
- Optimization of parameters by DoE in GT-Suite for each layout concept:
  - Assumption of fixed temperature differences for heat exchangers
  - Engine side water flows and temperature levels, target: reach maximum thermal efficiency
- Decision for best overall concept

Top of the Line Efficiency

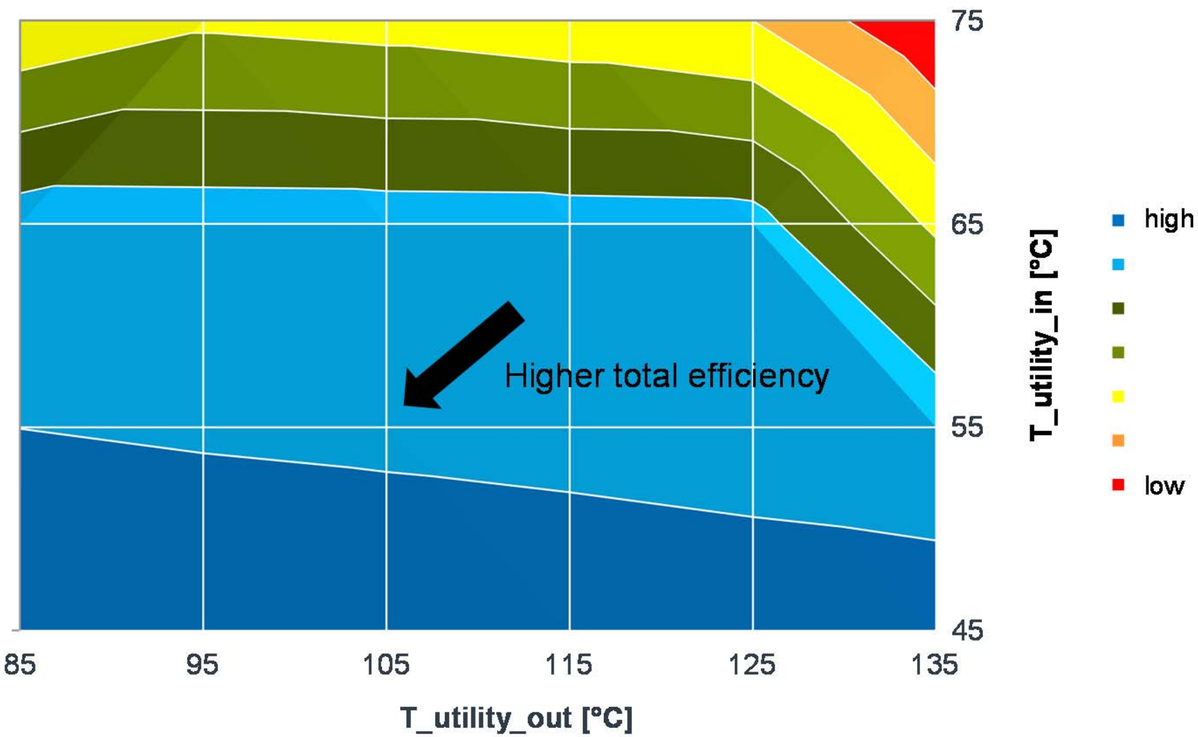
What is the Best Overall Concept?



- Constant earnings along the 4 lines shown
  - e.g. for power/heat value 2: loss of 1% η_{total} can be compensated by gain of 1% $\eta_{engine,el.}$
- Target for optimization:
  Max(C * $\eta_{engine,el.}$ + $\eta_{thermal}$)
  C : power/heat value

Optimization regarding application is needed with respect to energy type values

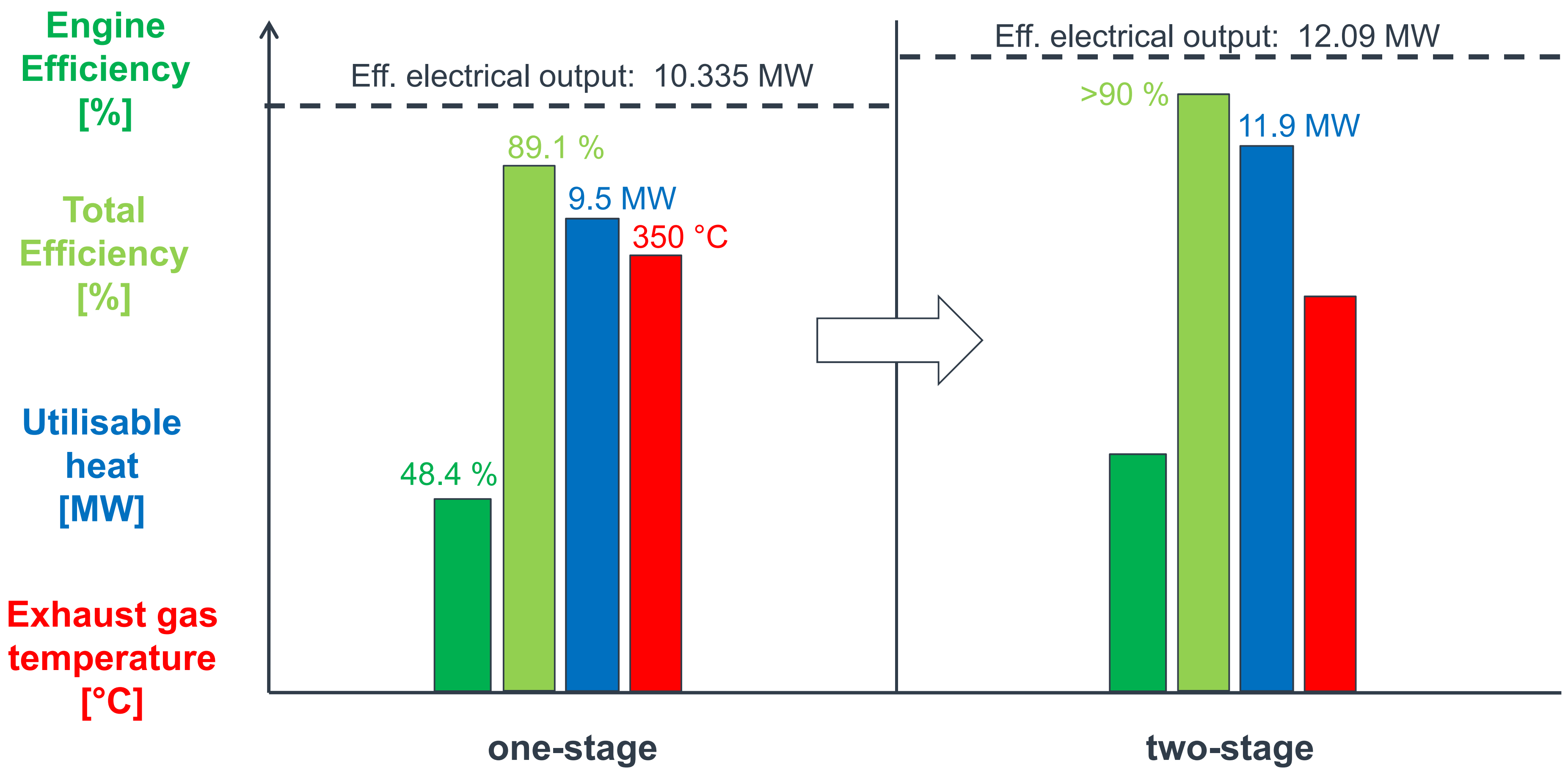
Top of the Line Efficiency
What is the Best Overall Concept?



- Heats available at certain temperature level
- Loss of heats that are below the current utility water level can be minimized by choosing an optimized system layout

Boundary conditions have impact on achievable efficiency

Efficiency Improvements CHP



Summary

- **Motivation for two-stage turbocharging**
  - Increased engine efficiency
  - Power density
  - Emissions reduction

- **Optimizations carried out for the new V35/44G TS**
  - Choice of charge air pressure control device
  - Advanced Miller valve timing
  - Gas admission timing
  - CHP optimization

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.

Do you have any more questions?

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