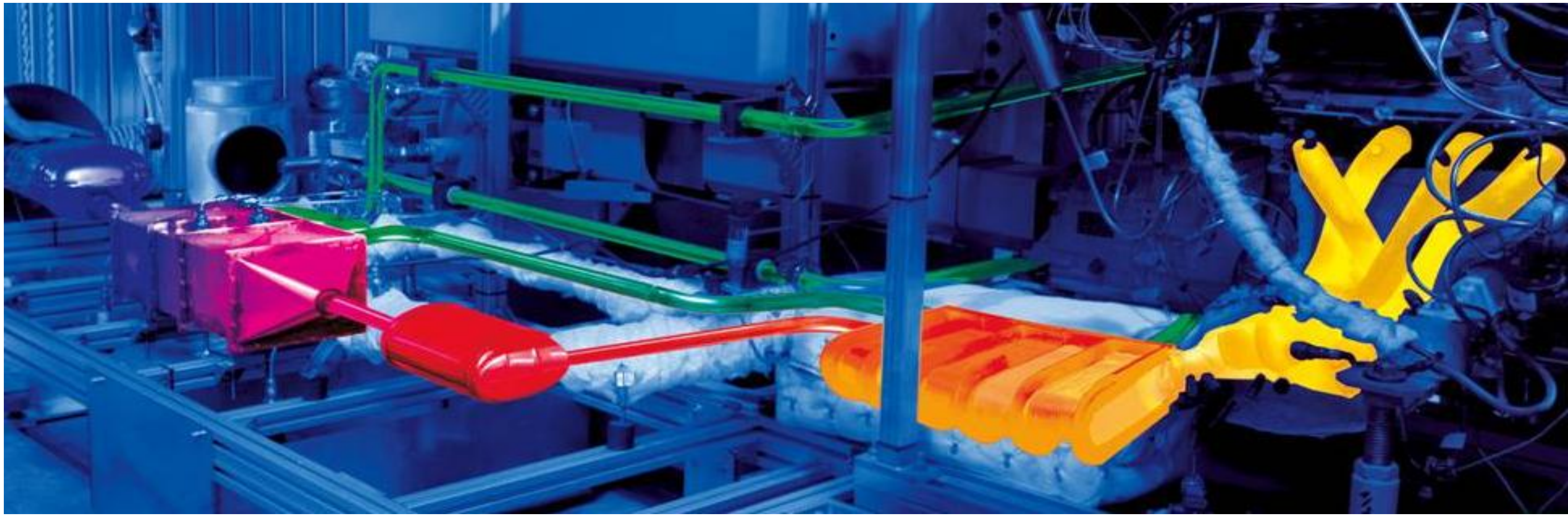
Future EfficientDynamics with Heat Recovery.



DEER 2009 – High Efficiency Engine Technologies.

A. Obieglo, J. Ringler, M. Seifert, W. Hall.

BMW Group
Research and Technology

Future EfficientDynamics with Heat Recovery.
Outline.

1. Efficient Dynamics
2. Heat Recovery
3. Heat Recovery Systems
4. BMW Turbosteamer
5. Conclusions

CO_2 – The Challenge.
Our Answer – Efficient Dynamics.

BMW 323i Model year 1983

BMW 325i Model year 2009

	BMW 323i Model year 1983		BMW 325i Model year 2009
Fuel consumption[1]	10.3 l/100 km [~22 MPG]	- 31 %	7.1 l/100 km [~33 MPG]
Power output	102 kW	+ 57 %	160 kW
Torque	205 Nm	+ 32 %	270 Nm
Acceleration[2]	9.2 s	- 27 %	6.7 s
Emission quality	ECE R15-04	+ 95 %	EU 4
Weight	1080 kg	+ 39 %	1505 kg
Drag	0.40 x 1.85 m²	- 21 %	0.27 x 2.17 m²

[1] **EU fuel consumption MVEG**

[2] 0 - 100 km/h

Efficient Dynamics.
BMW's Approach to Reduce CO_2.

Powertrain
- Direct fuel injection
- DI2 lean stratified
- Piezo injectors
- High precision injection
- Turbo
- Twin turbo
- Variable twin turbo
- Downsizing
- Gearbox efficiency
- Gearbox spreading

Aerodynamic
- External flow
- Internal flow
- Wheel/enclosed wheel
- Flexible flaps

Rolling resistance
- Tires with reduced rolling resistance

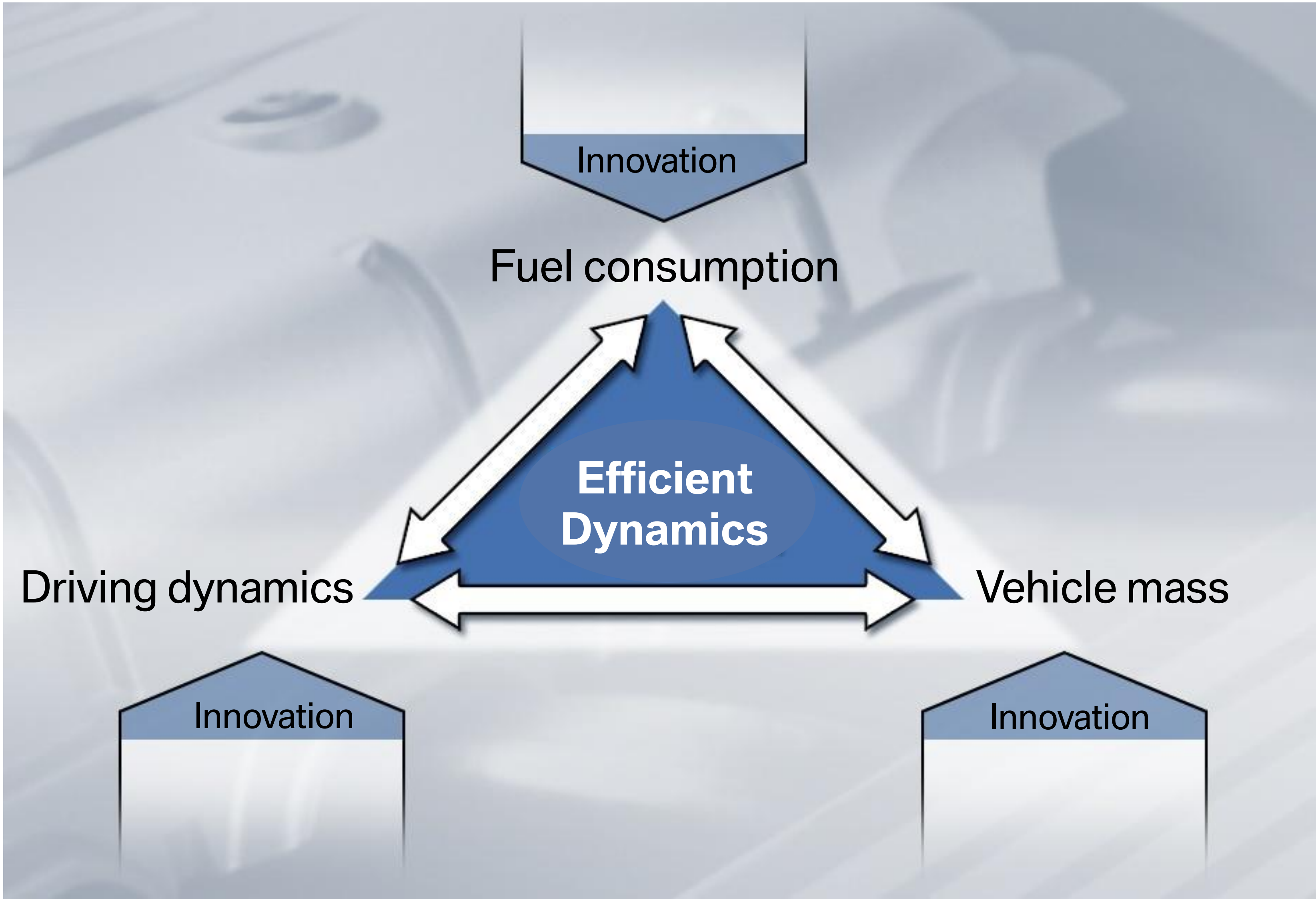
Energy management
- Auto Start Stop function
- Brake energy regeneration
- Electr. assist
- Electr. driving
- Demand-oriented drive
- Electr. waterpump
- Electr. steering
- Air conditioning compressor division
- Electr. driving dynamic systems

Lightweight construction
- Conceptual
- Materials
- Production

Heat management
- Aggregate cooling on demand
- Rapid heat-up
- Insulation
- Friction reduction

Energy source
- Fuel
- Diesel
- Natural Gas
- Alternative fuels
- GTL, BTL
- Hydrogen

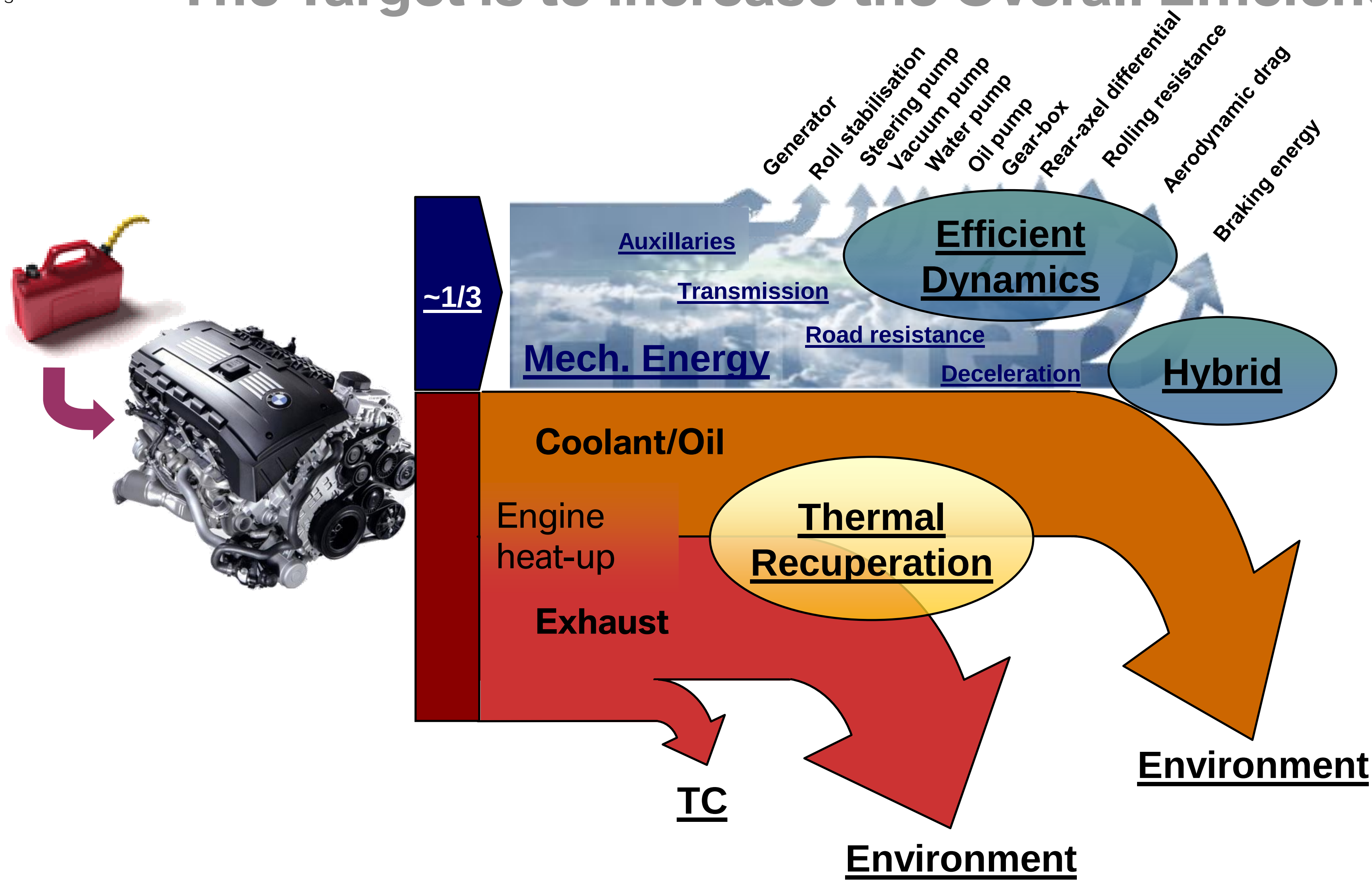
Efficient Dynamics.
BMW's Approach to Reduce CO_2.



Future EfficientDynamics with Heat Recovery.
Outline.

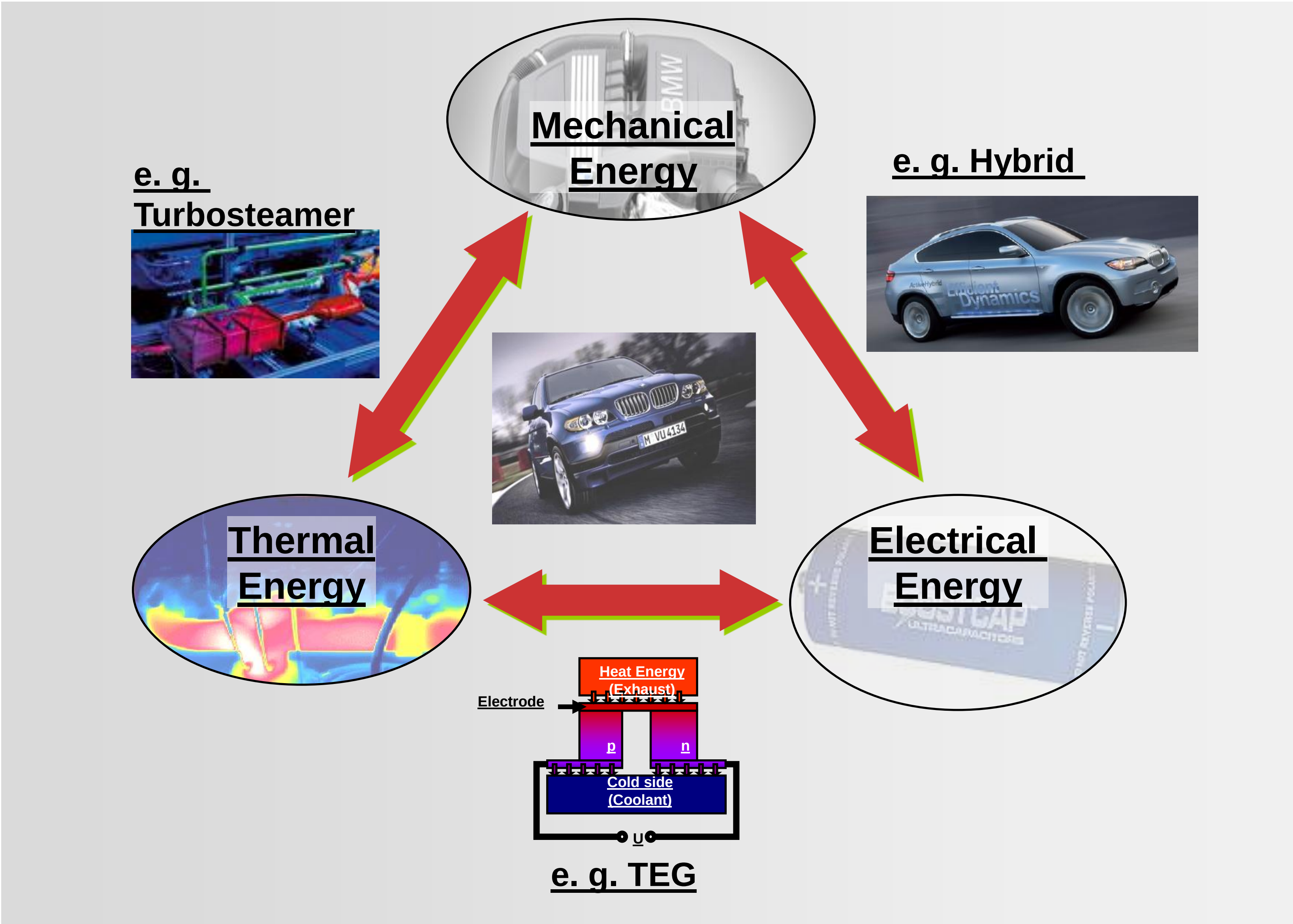
Energy Efficiency of Vehicles.

The Target is to Increase the Overall Efficiency.



~2/3 of the energy contained in the fuel is converted into heat

Energy Conversion.
Different Possibilites.



Efficient Dynamics.
Steps towards Heat Recovery.

1. **Direct Conversion**
   Highly efficient primary energy conversion:
   - High Precision Injection
   - TwinPower Turbo
   - Valvetronic

2. **Warming-up**
   Faster warming-up: No coolant circulation with electrical water pump switched off.

3. **Waste Heat Recovery**
   Example of waste heat utilization: Turbosteamer

Future EfficientDynamics with Heat Recovery.
Outline.

1 Efficient Dynamics

2 Heat Recovery

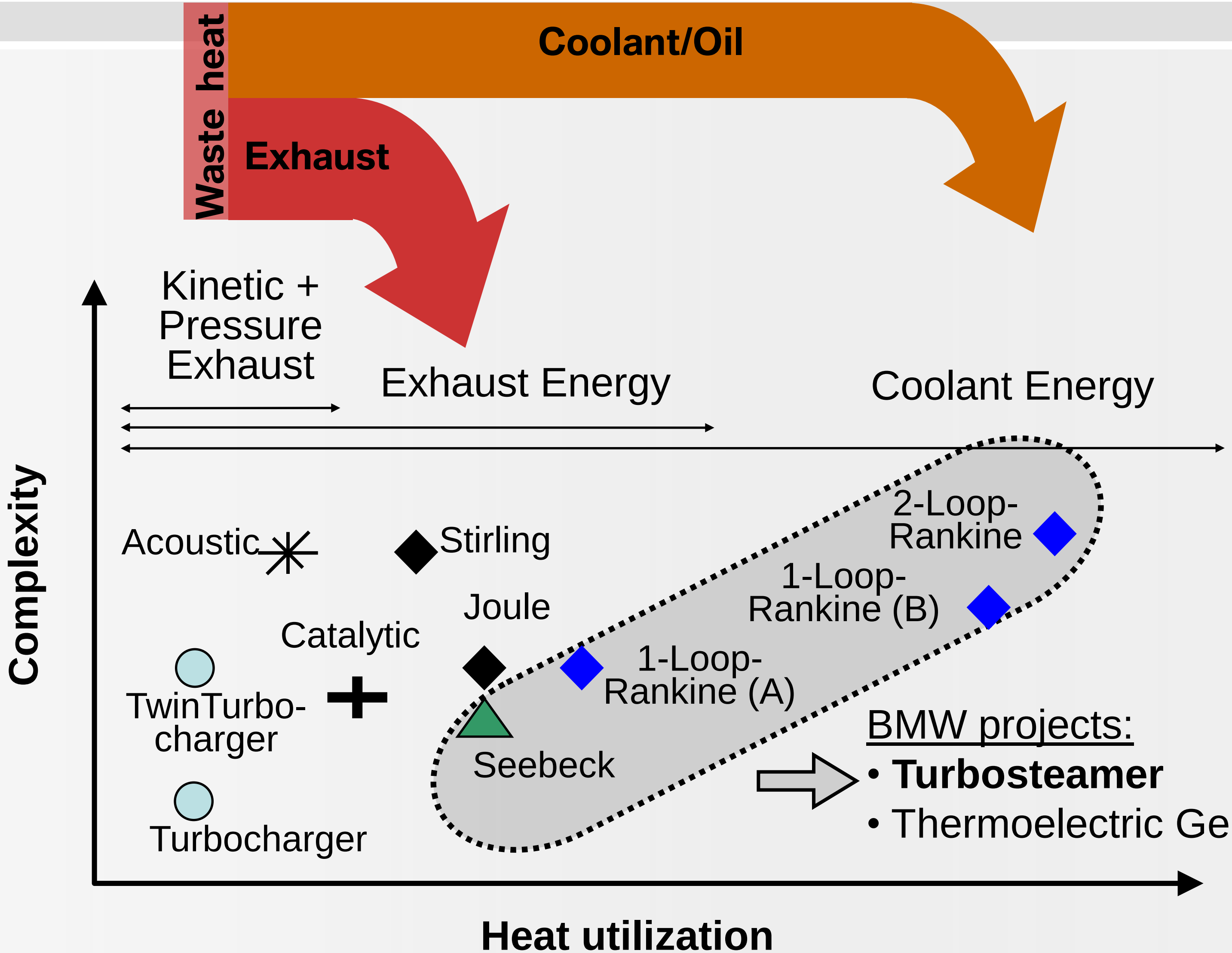
3 **Heat Recovery Systems**

4 BMW Turbosteamer

5 Conclusions

Energy Efficiency of Vehicles.

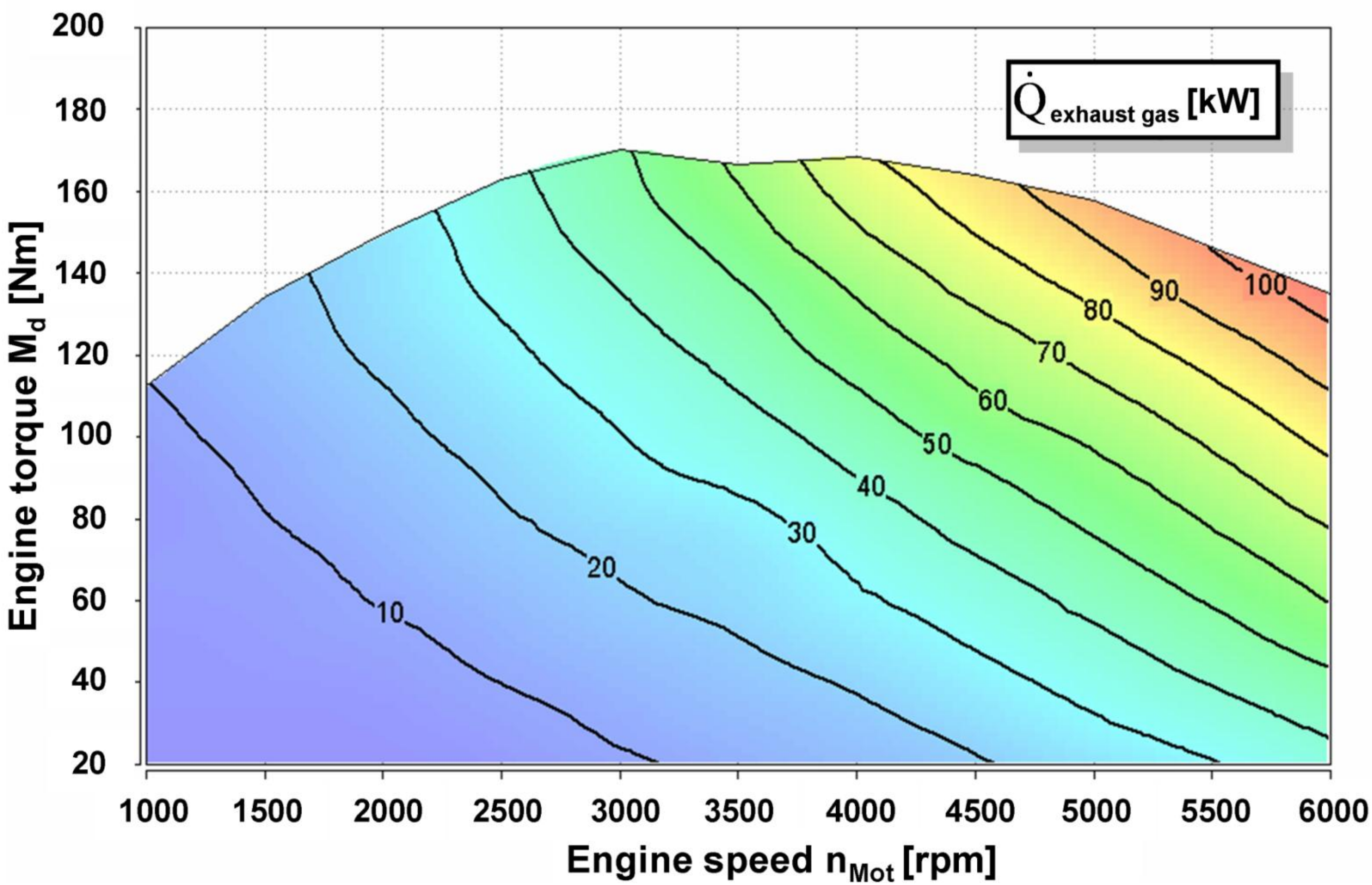
Thermal Recuperation offers the Potential of Additional CO_2 Reduction.



BMW projects:
- **Turbosteamer**
- Thermoelectric Generator

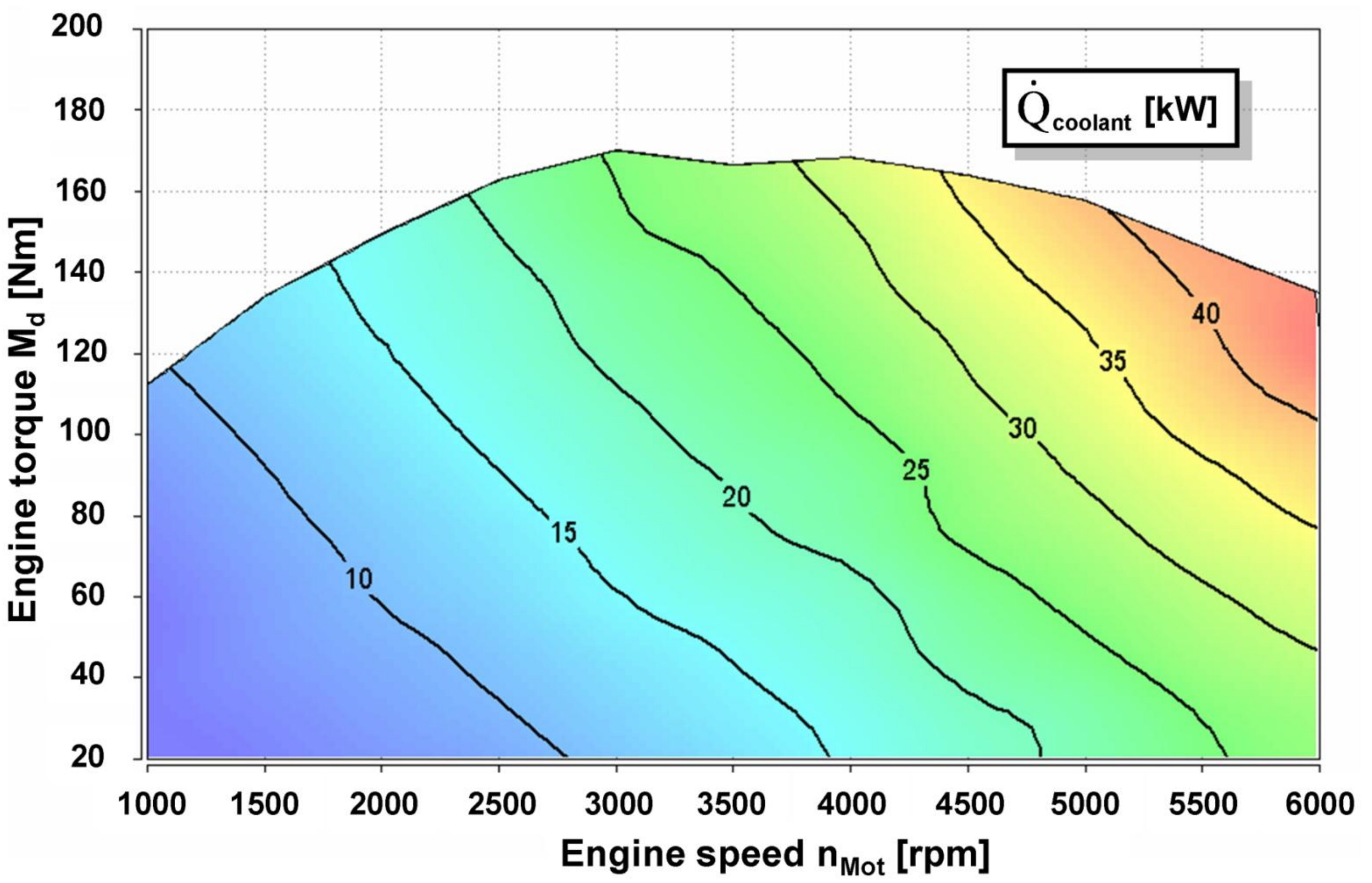
Heat Sources.
Exhaust Gas.

Engine type: 4-cylinder gasoline engine λ=1

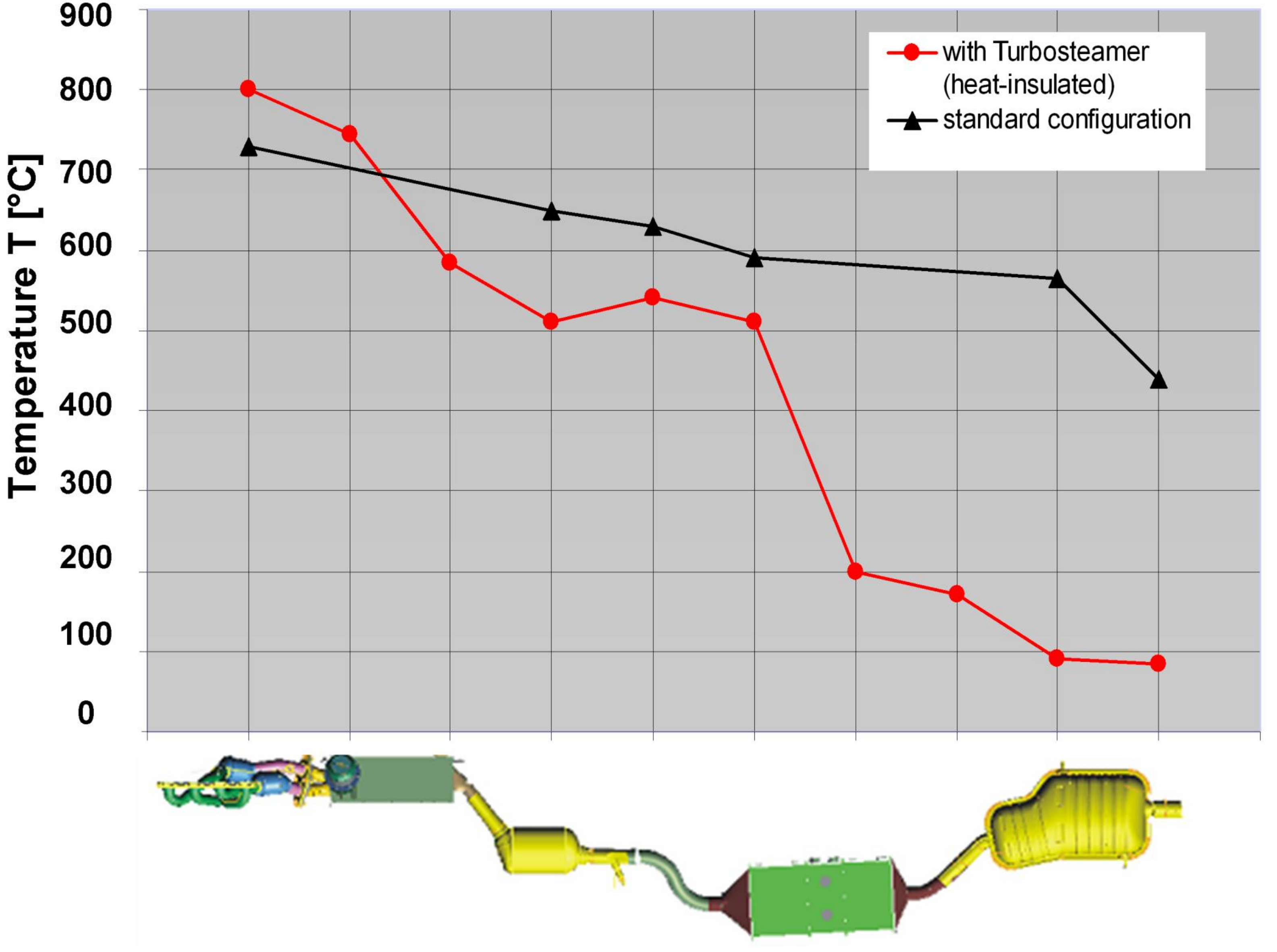


Heat Sources.
Coolant.

Engine type: 4-cylinder gasoline engine λ=1



Utilization of Exhaust Heat.
Temperature Distribution.



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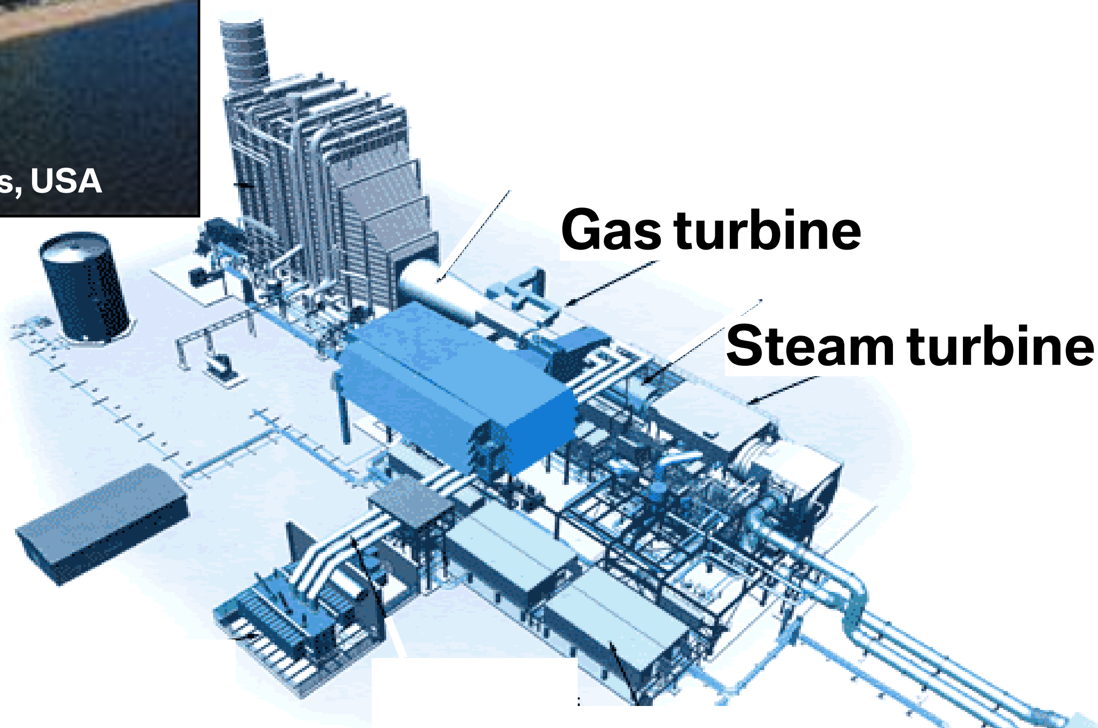
What is a Turbosteamer (TS)?
Cogeneration a well known Principle.

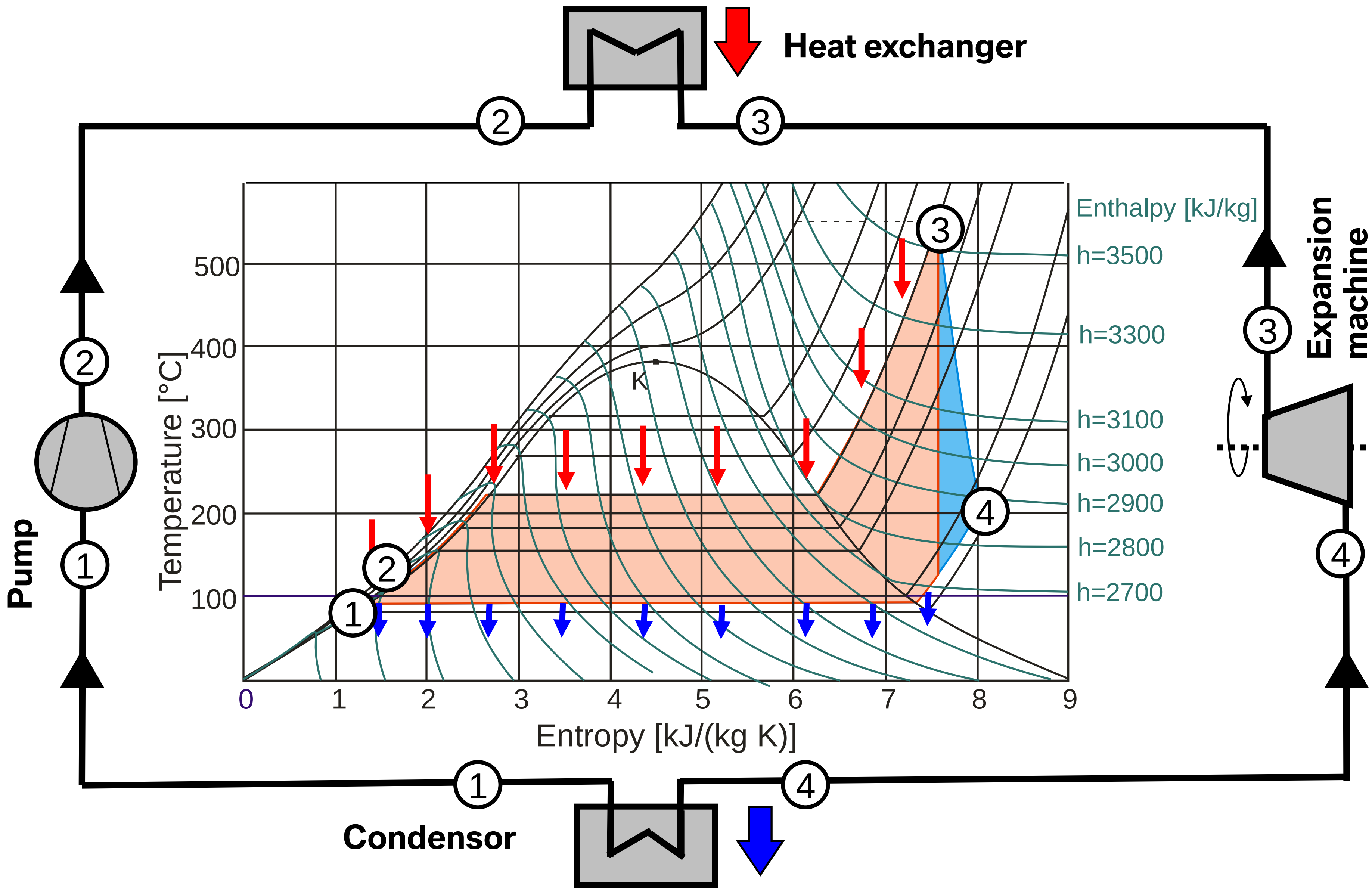
700 MW, Edinburg, Texas, USA

76 MW, Huelva, Spain

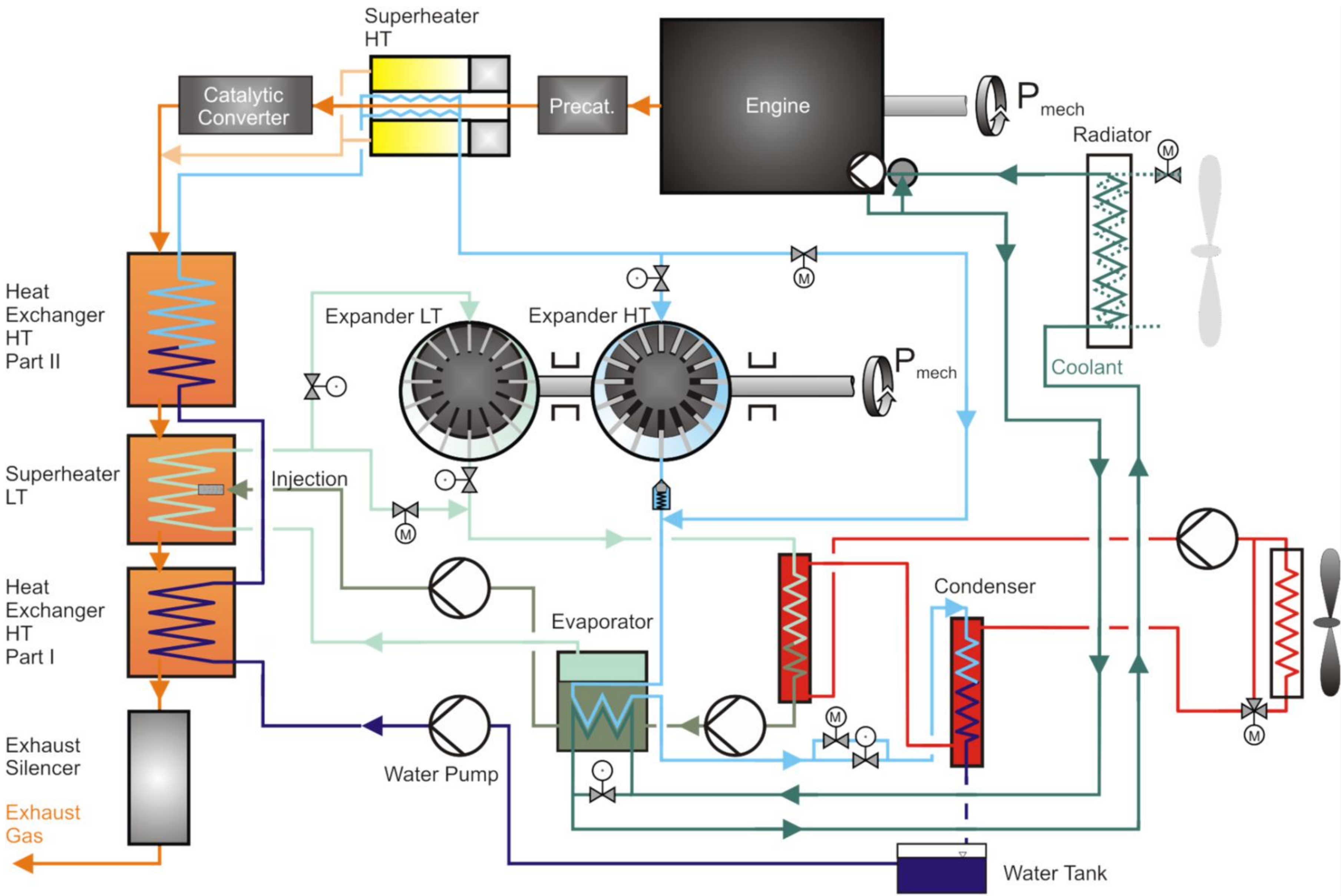


Source:
Siemens Powergeneration

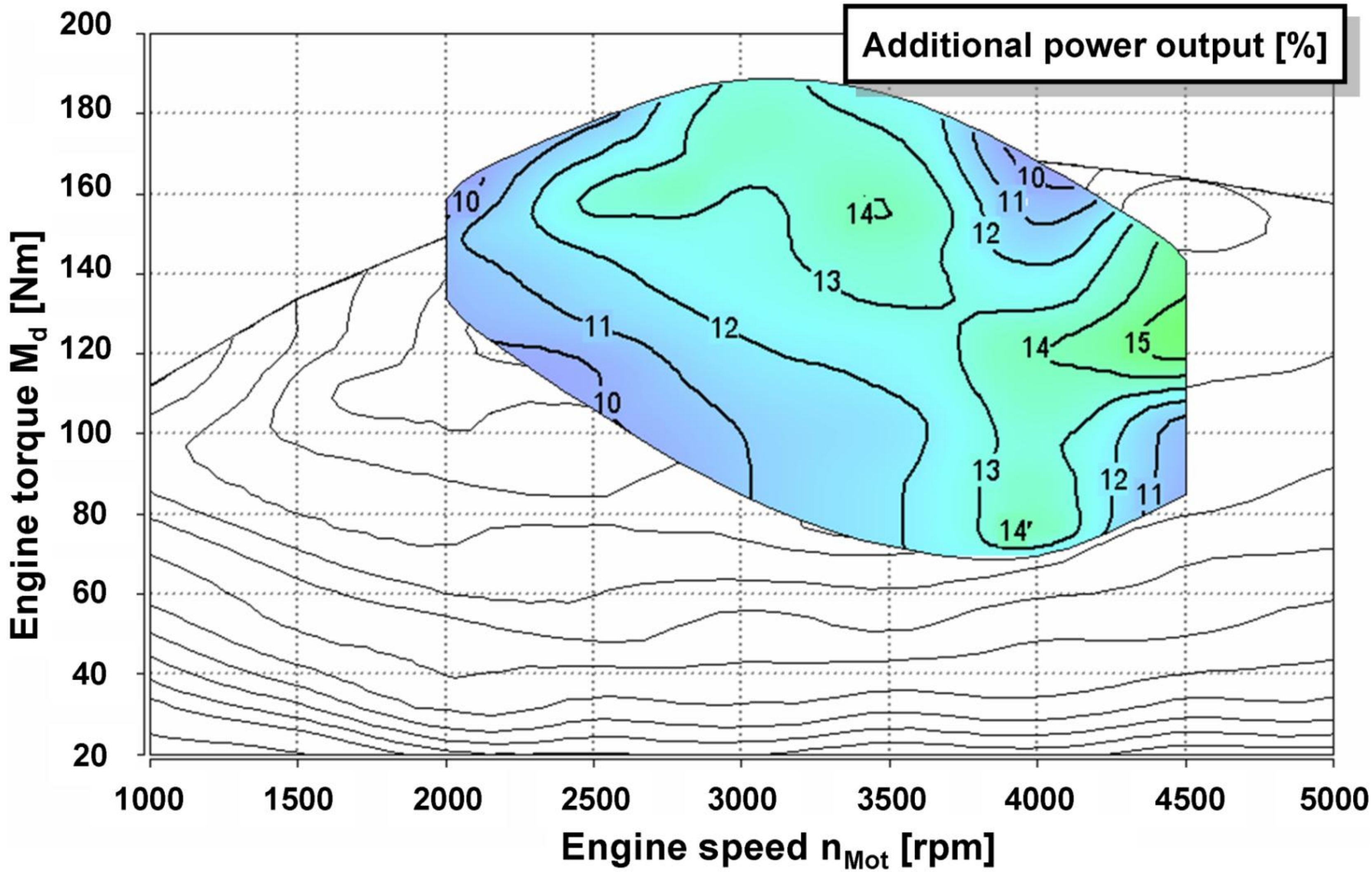
Basic System Layout of a Turbosteamer.
Working Principle of a Rankine Steam Process.



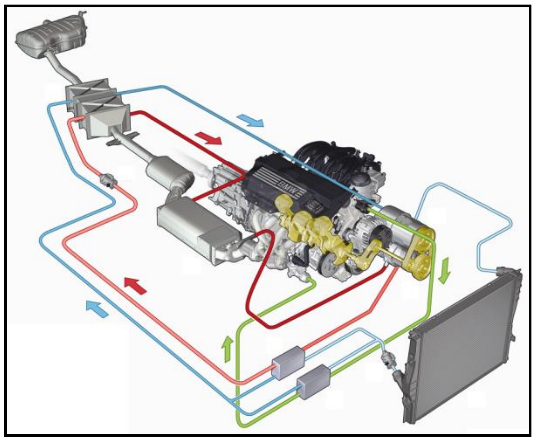
Dual-Loop-Rankine.
Maximal Utilization of Exhaust and Coolant.

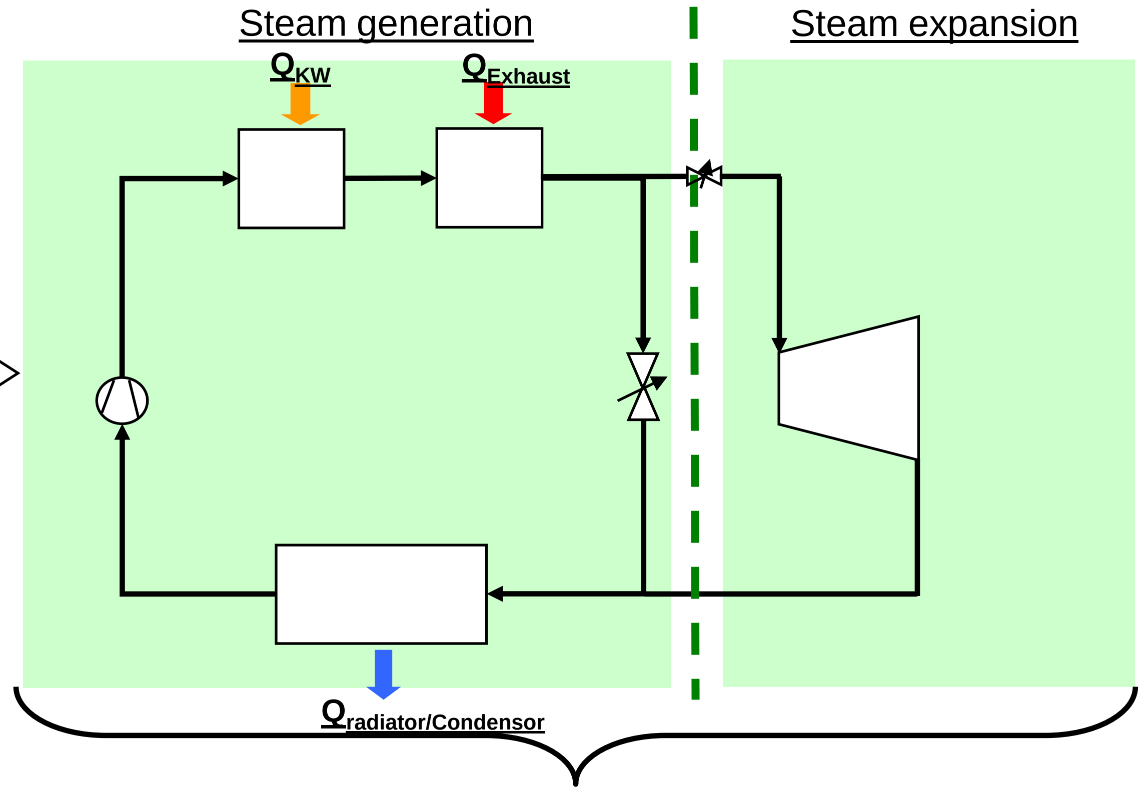


Dual-Loop-Rankine.
Engine Map.



Single-Loop-Rankine.
Simplification of the System.





Dual-Loop-Rankine

2 Expanders, 2 Loops

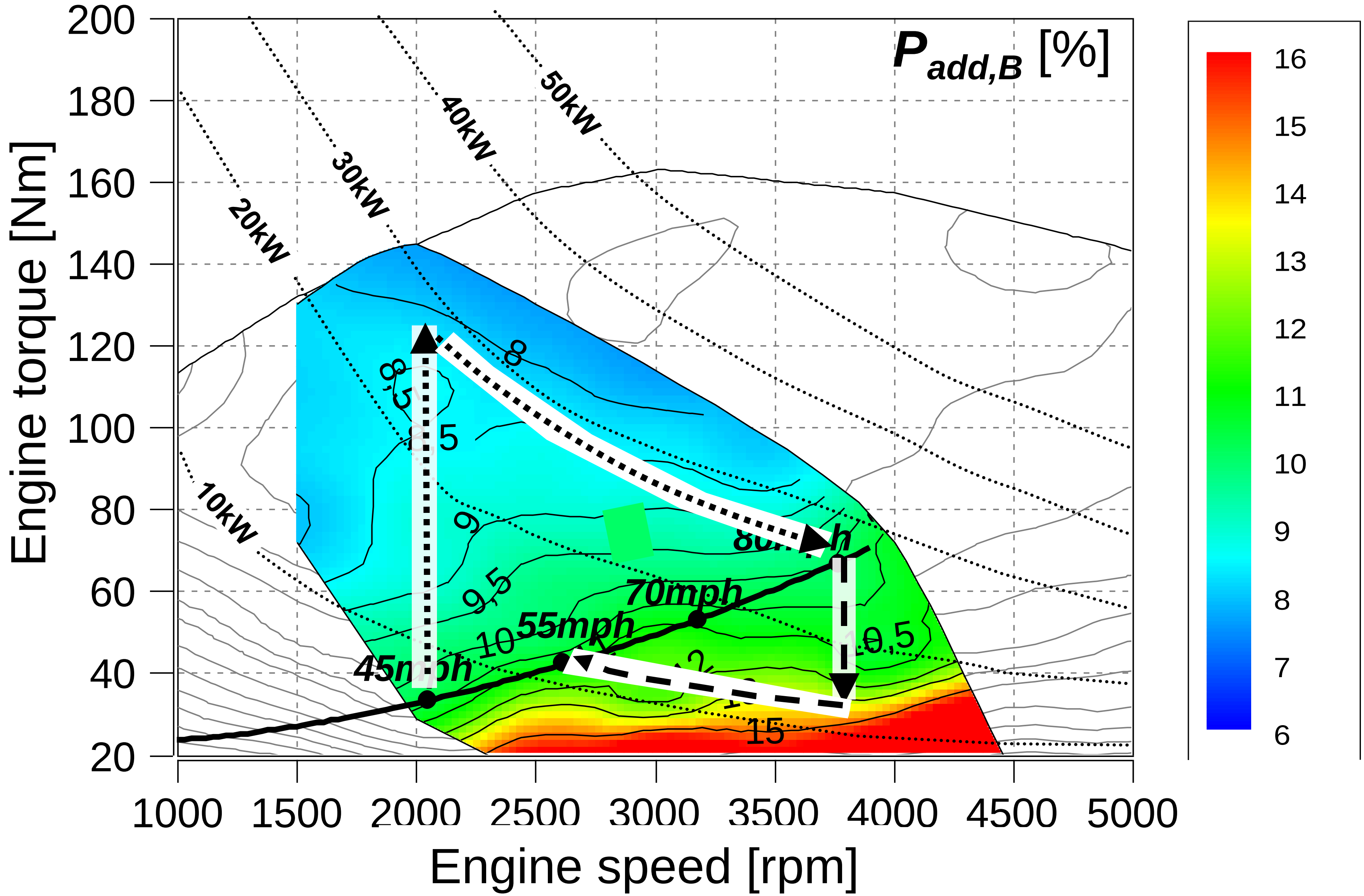
- maximum potential
- complete use of heat
- complex system

Single-Loop-Rankine

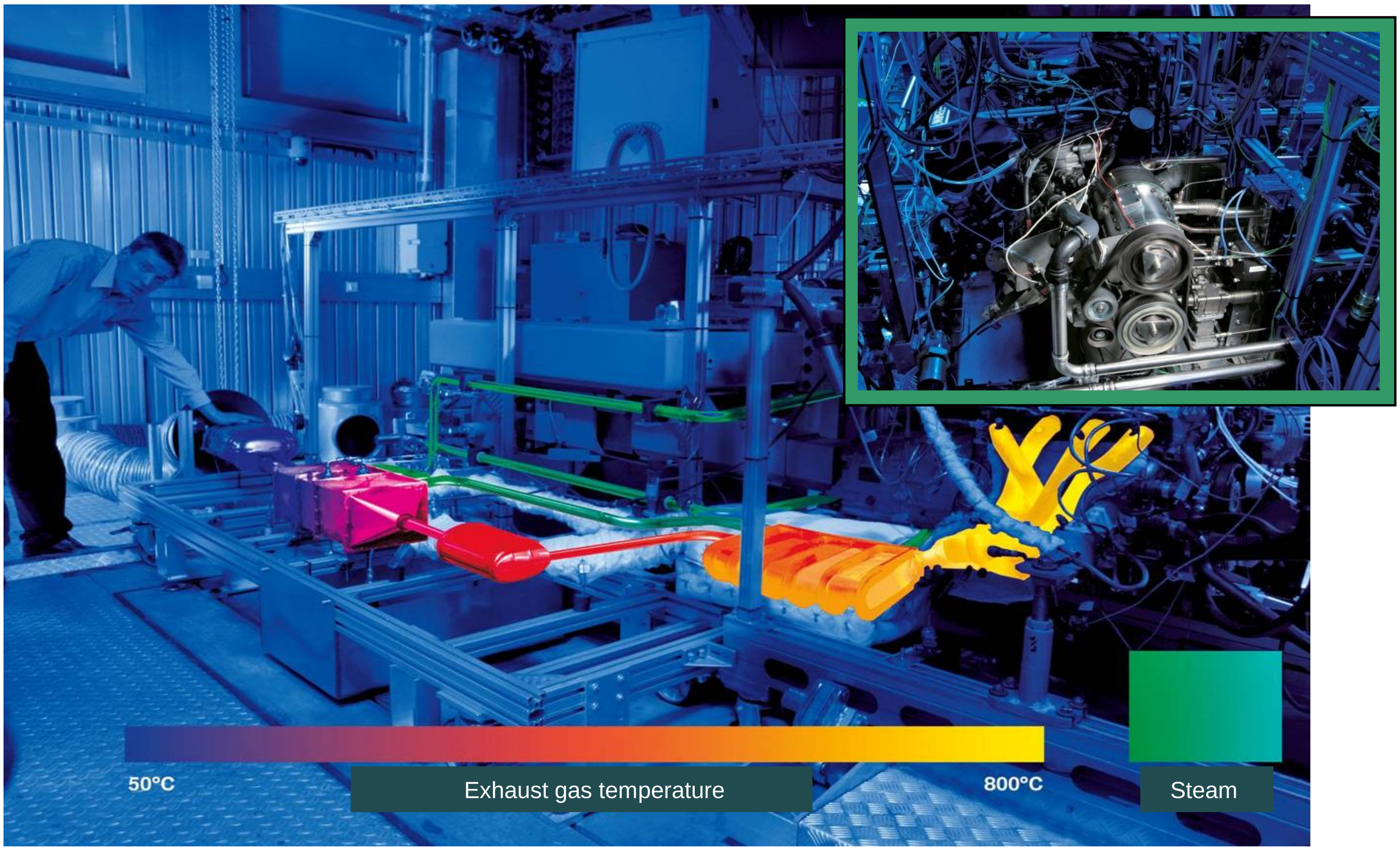
1Expander, 1 Loop

- Simplification
- improved ratio of effort/use

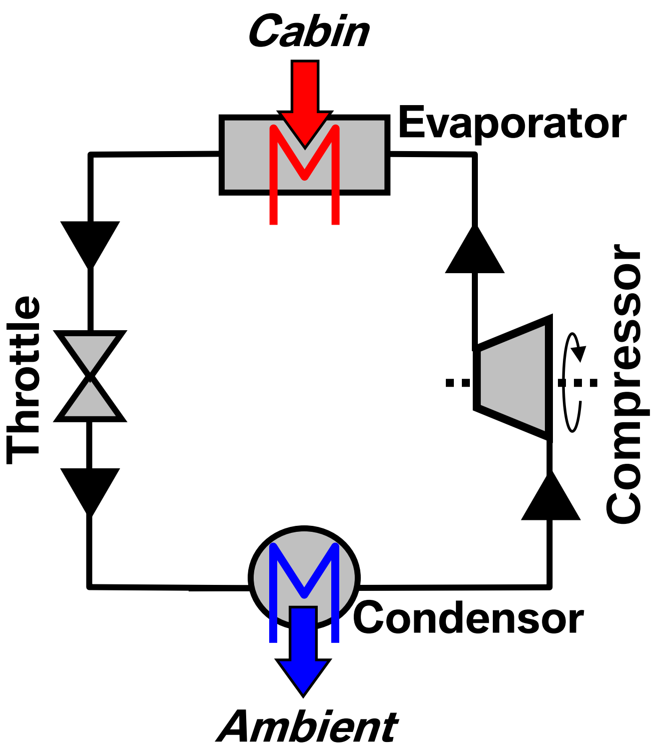
Single-Loop-Rankine.
Significant Increase in Fuel Efficiency.

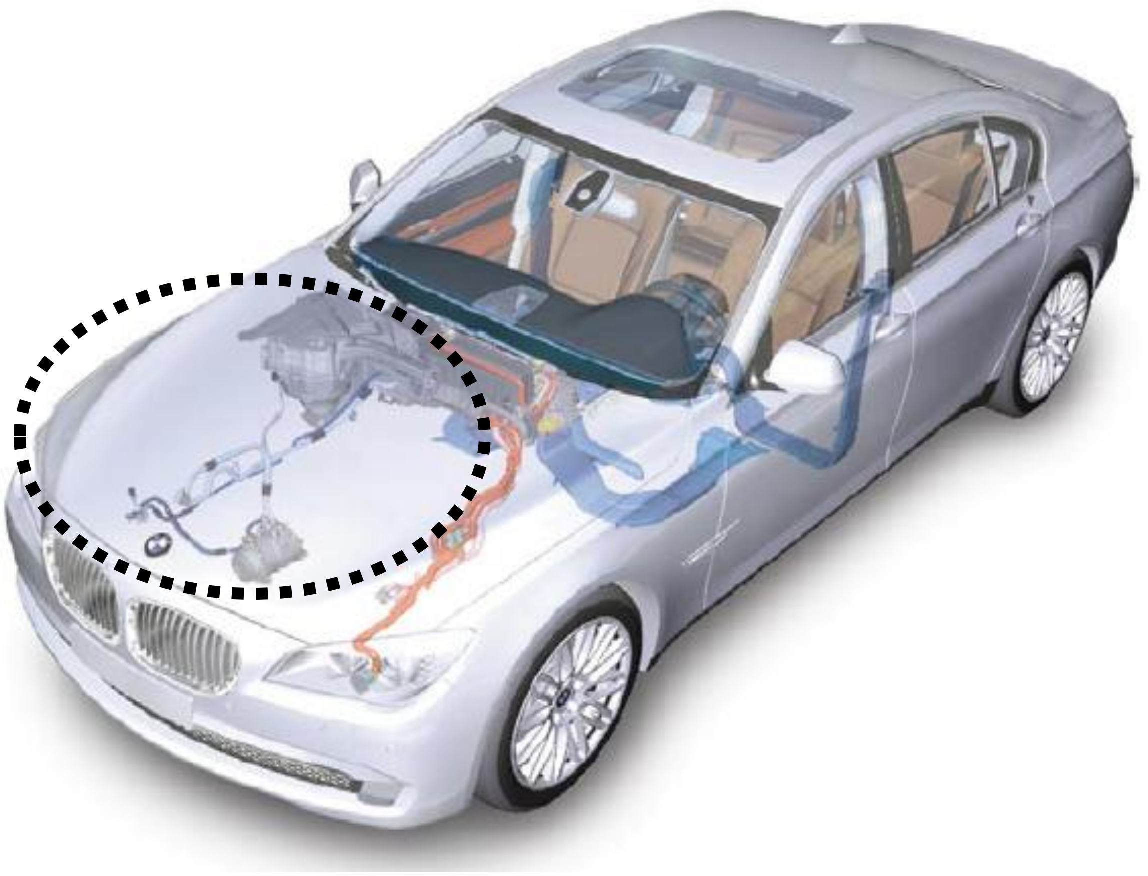


Turbosteamer in Operation.
Turbosteamer Test Bench Setup.



A similar System in almost every Car Today:
Have a look on Air Conditioning.





Turbosteamer Components.
For Example: Expander.

**A/C Compressor
1976**

**Today‘s Generation
A/C compressor**

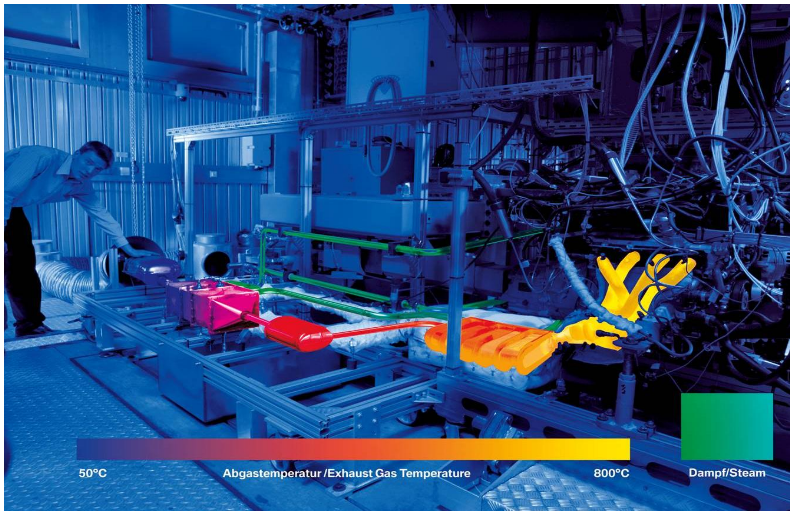
**First Generation
Turbosteamer Expander**

?

**Future Generation
Turbosteamer Expander**

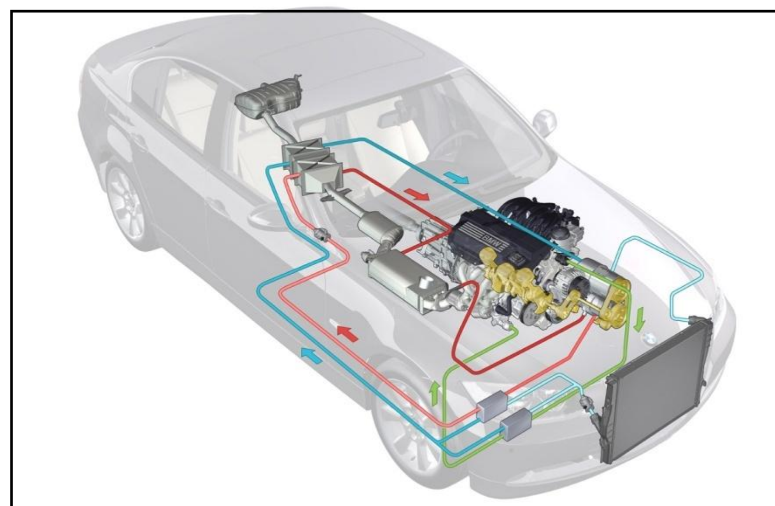
Waste Heat Recovery with the Turbosteamer.
Next Steps.

Weight and designed-space reduction



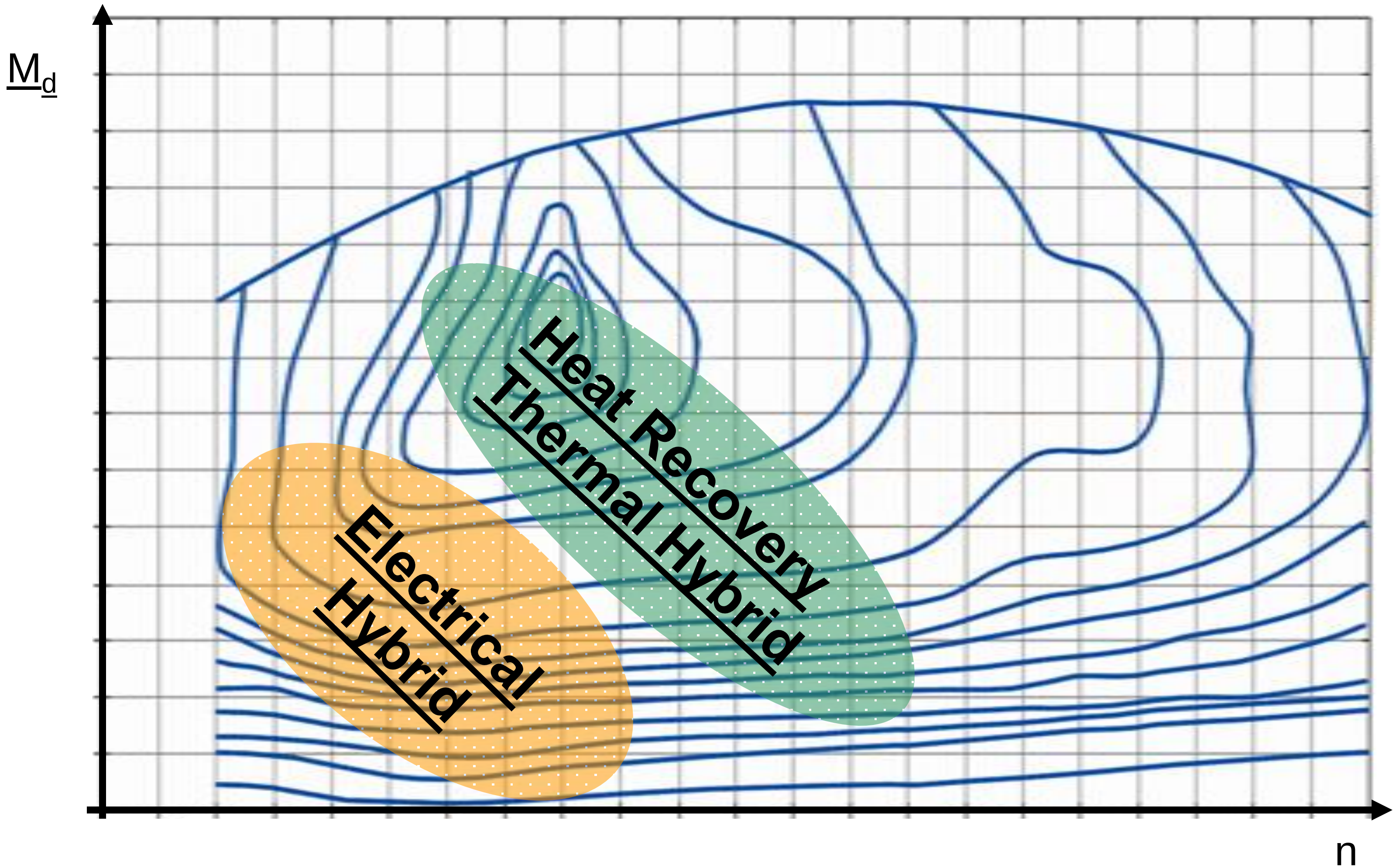
TS test bench

Cost reduction



TS vehicle integration

Efficient Dynamics and Energy Recovery.
Positioning of Systems in the Engine Map.



Potential Savings.
Heat Recovery.

What are the savings for a long distance driver at mileage of 120,000 miles?	Today	Future
Take for example a car with	25 mpg	35 mpg
… the overall consumption would be	4,800 gallon	3,400 gallon
Assuming that additional 5 to 10% of fuel could be saved:		
That is less	240-480 gallon	170-340 gallon
With a price of	3$/gallon	5$/gallon
… the saving for this driver is	$720-1,440	$850-1,700

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Waste Heat Recovery with the Turbosteamer.
Conclusions.

1. Thermal recuperation offers the potential of additional CO_2 reduction.

2. The Rankine steam process is one favourable approach for waste heat recovery.

3. A 15% increase in engine performance could be demonstrated with a Dual-Loop-Rankine and 10% increase in engine performance could result from a Single-Loop-Rankine.

Vision.

Thermal Recuperation could make a valuable Contribution to the Increase in Fuel Efficiency.