Efficient and Dynamic – The BMW Group Roadmap for the Application of Thermoelectric Generators.

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BMW Group
BMW EfficientDynamics.
Mobility is essential for economic success and quality of life.
BMW EfficientDynamics.
Hybrid technology and CO$_2$ edition models complete our premium products.

ActiveHybrid 7
- Performance: 342 kW
- CO$_2$-Emission: 219 g/km *
- Consumption: 9,4l/100 km (25mpg) *

X6 ActiveHybrid
- Performance: 430 kW
- CO$_2$-Emission: 231 g/km *
- Consumption: 9,9l/100 km (23mpg) *

320d EfficientDynamics Edition
- Performance: 120 kW
- CO$_2$-Emission: 109 g/km *
- Consumption: 4,1l/100 km (57mpg) *

* Basis: New European Driving Cycle
BMW EfficientDynamics.
The BMW Group reduced the CO₂ emissions of its fleet by ~29 % (1995-2009) in Europe.

The BMW Group fulfilled its ACEA commitment and reduced CO₂ emissions for its fleet by almost 29 % during the period from 1995 to 2009.

This reduction is unmatched by any other car company.
BMW EfficientDynamics.
Our strategy middle and long-term.

BMW EfficientDynamics strategy

2007 / 2008

2009

2010

Otto / Diesel
Efficient Dynamics
Hydrogen

Mild Hybrid
Full Hybrid
Electric vehicle
BMW EfficientDynamics.
On-board electricity is not for free.
BMW Efficient Dynamics.
When is most of the fuel used?

→ ~60% of the fuel is used for long-distance trips per year in Germany.

Source:
• R. Thom, Fa. CAR
• Federal Statistical Office, Germany
BMW EfficientDynamics.
Energy fluxes for a BMW Powertrain.

~2/3 of the energy contained in the fuel is converted into heat which is not used today.
BMW EfficientDynamics

Waste Heat Recovery is one essential component to uncharge the alternator in future.

Our Vision:

The engine will only be switched on for acceleration and at cruising speed

Ancillaries are all powered by electrical power from the following sources:
Thermoelectric Waste Heat Recovery.
The maximum power which can be recovered from the exhaust gases is attractive!

Basis: BMW 535i, NEDC

Real cycle: ~"50% of Carnot Efficiency"

Conversion into FC-reduction: ("Willans Approach" for the NEDC)

Conversion into mechanical power: 0.4 l/100km
Conversion into electrical power: 0.6 l/100km
(in case the electrical power is completely used)

Ideal cycle (Carnot)

Heat loss in the exhaust gas heat-exchanger.

~33%

~33%

~33%

3.8 kW

2.4 kW

0.9 kW

0.45 kW

NEDC: (European Driving Cycle)
100 W correspond to
0.13 l/100km ≈ 3 g CO₂/100km (gas.)
0.10 l/100km ≈ 2.7 g CO₂/100km (Diesel)

US-Combined Driving Cycle
100 W correspond to
0.10 l/100km ≈ 2.3 g CO₂/100km (gas.)

Penalties per Gram CO₂ in the EU:
95 €/g in 2020
Thermoelectric Waste Heat Recovery.
TEG vehicle implementation.

Bi$_2$Te$_3$ TEG (2007)
and
High-temperature TEG,
P$_{\text{max}}$ = 300W (2009)

Eco-Globe 2008 for the BMW development of a prototype TEG system
Thermoelectric Waste Heat Recovery. Possible locations for a TEG.

A TEG in a vehicle requires:
- Water supply
- By-pass (backpressure / max. cooling power)
- Heat Exchanger
- High Temperature / high massflow

Integration into the main exhaust system of a gasoline engine („underfloor location“):
- very high integration effort
- Obstacles:
  - Bypass (flap: possible but expensive)
  - connection to cooling system
- Advantage: highest recuperation potential
Exhaust gas recirculation reduces NOx emissions by reducing the combustion temperature in Diesel engines.

Thermoelectric Waste Heat Recovery.
We were looking for locations for an efficient TEG integration solution: The EGR cooler!
Integration into the main exhaust system of a gasoline engine:
- very high integration effort
  - Obstacles:
    → Bypass (flap: possible but expensive)
    → connection to cooling system
+ Advantage: highest recuperation potential

Integration into the EGR cooler for a Diesel engine:
- Easier to integrate:
  + Control for massflow (EGR Valve)
  + Cooling water already there!
- Disadvantage: Reduced recuperation potential compared to the integration into the main exhaust line

Thermoelectric Waste Heat Recovery. Possible locations for a TEG.
Thermoelectric Waste Heat Recovery. The EGR TEG does not require much room in the engine compartment.

Thermoelectric Waste Heat Recovery.

The EGR-TEG unit consists of a TEG section and a conventional cooler section.
Thermoelectric Waste Heat Recovery.
The EGR TEG unit – TEG section.
Thermoelectric Waste Heat Recovery. The EGR TEG unit – interactions with the Diesel engine are investigated.

Fouling, Operating Strategy, …
Thermoelectric Waste Heat Recovery.
The TEG power is very attractive.
Thermoelectric Waste Heat Recovery.
The BMW Group roadmap is challenging and possible!

2018

TEG integrated in Cat. Converter

2022

1000W

Underfloor TEG

500W

EGR-TEG

Material: PbTe
Application in the EU until 2018 pending.

Lead-free TE Material

TEG-Power

Regenerated

Material: PbTe
Application in the EU until 2018 pending.
Thermoelectric Waste Heat Recovery.

The BMW Group roadmap is challenging and possible!
Thermoelectric Waste Heat Recovery.
The next milestone in the TEG development will be drivable soon...
Thank you for your attention!

Thomas Seebeck

BMW Group