A3PS

Rethinking Propulsion.

Thermal Management of Hybrid Electric Vehicles

Gerhard Lux, Stefan Winter, Peter Hofmann, Bernhard Geringer

Hybrid and electric vehicles, energy storage technologies and control systems

National and international R&D-projects, research institutions and funding programs

Vienna, October 21st 2008

in cooperation with bmvit and arsenal research

Ein Unternehmen der Austrian Research Centers

Content

- Introduction
- Simulation Model
- Fuel Saving Potential
- Thermal Management Concepts
  - Utilization of Thermal Power Losses
  - Heat Storage
  - Utilization of Exhaust Gas Heat
- Conclusions

Content

- Introduction
- Simulation Model
- Fuel Saving Potential
- Thermal Management Concepts
  - Utilization of Thermal Power Losses
  - Heat Storage
  - Utilization of Exhaust Gas Heat
- Conclusions

Introduction

Some power train elements show a considerably lower efficiency in cold condition than at operating temperature:

- Engine
- Transmission
- Axle Transmission

Thermal Management:

control of heat flows in the vehicle dependent on the heat requirements of the components

→ Shorter warm-up phase

Introduction

Two different concepts to reduce fuel consumption:

- Hybridization
- Thermal Management

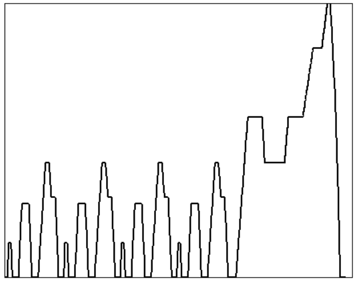
Is there an extra benefit in combining these two?

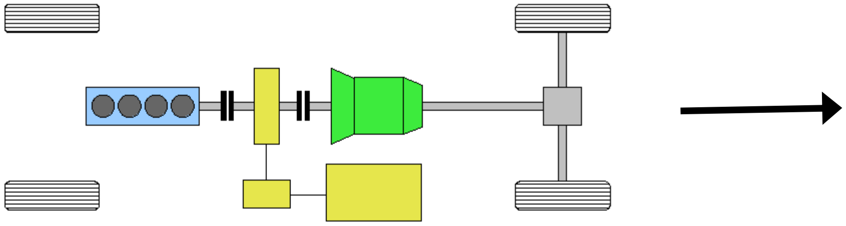
Content

- Introduction
- Simulation Model
- Fuel Saving Potential
- Thermal Management Concepts
  - Utilization of Thermal Power Losses
  - Heat Storage
  - Utilization of Exhaust Gas Heat
- Conclusions

Simulation

Vehicle model for longitudinal simulation





fuel consumption

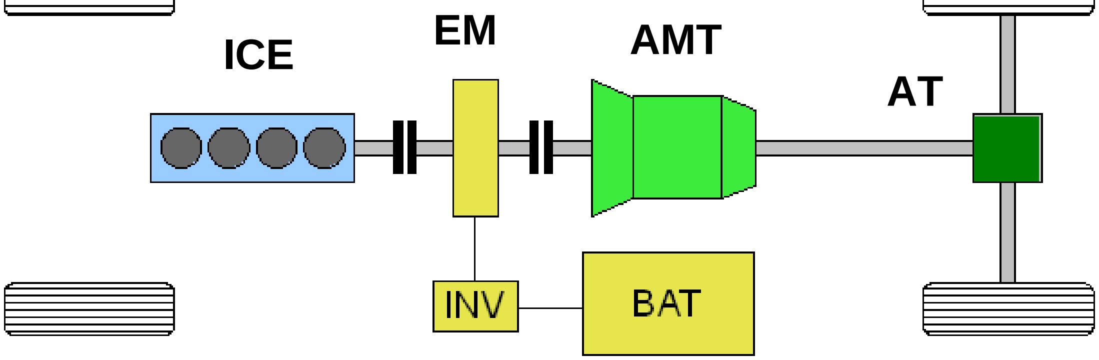
Extension of the simulation model:

Thermal behavior of the power train components

- warm-up behavior
- temperature dependence of the component efficiencies

Vehicle

Parallel Hybrid:



ICE	**internal combustion engine**
EM	**electric machine**
AMT	**automated manual transmission**
AT	**axle transmission**
INV	**inverter**
BAT	**battery**

Conventional Vehicle:

ICE: 147 kW
mass: 1885 kg

→

Hybrid:

EM: 35.5 kW
BAT: 2.6 kWh
mass: 2045 kg

Operating Strategy

Operational states:

1. **Start / Stop**
2. **Regenerative Braking**
3. **Load point shifting**
4. **Electrical driving**
5. **Boost**
6. **ICE driving**

Content

- Introduction
- Simulation Model
- Fuel Saving Potential
- Thermal Management Concepts
  - Utilization of Thermal Power Losses
  - Heat Storage
  - Utilization of Exhaust Gas Heat
- Conclusions

Fuel Saving Potential (NEDC)

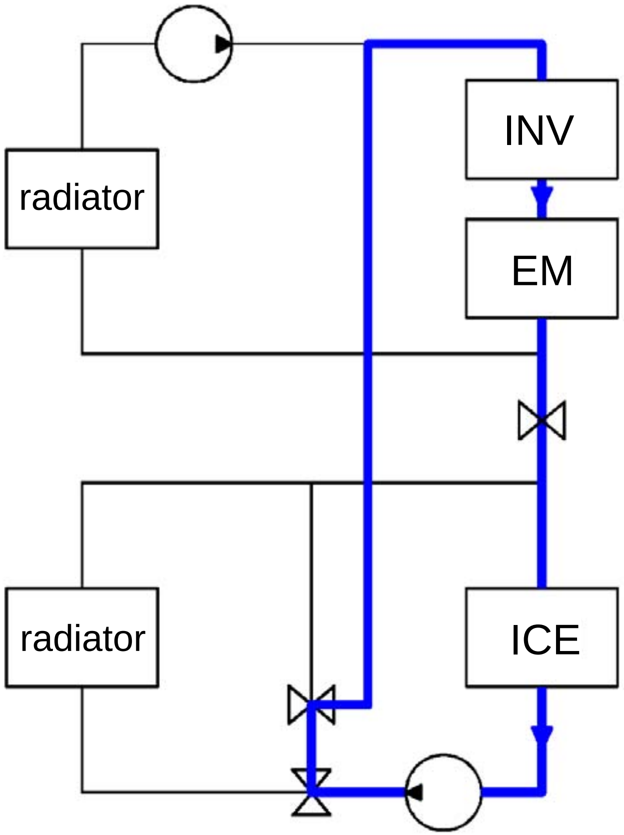
engine	transmission	axle transmission	fuel consumption, reduction	conventional vehicle	hybrid vehicle
cold	cold	cold	fuel consumption (reference)	9.06 l/100km	7.03 l/100km
warm	cold	cold	fuel consumption	8.72 l/100km	6.74 l/100km
			reduction	3.7 %	4.2 %
warm	warm	cold	fuel consumption	8.65 l/100km	6.64 l/100km
			reduction	4.5 %	5.5 %
warm	warm	warm	fuel consumption	8.55 l/100km	6.56 l/100km
			reduction	5.7 %	6.6 %

Content

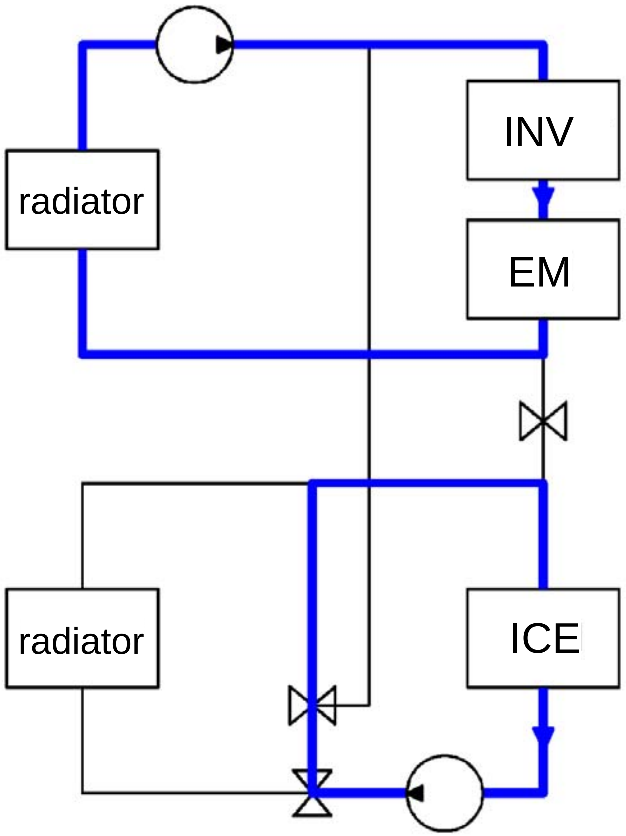
- Introduction
- Simulation Model
- Fuel Saving Potential
- Thermal Management Concepts
  - Utilization of Thermal Power Losses
  - Heat Storage
  - Utilization of Exhaust Gas Heat
- Conclusions

Utilization of thermal power losses of the electrical components

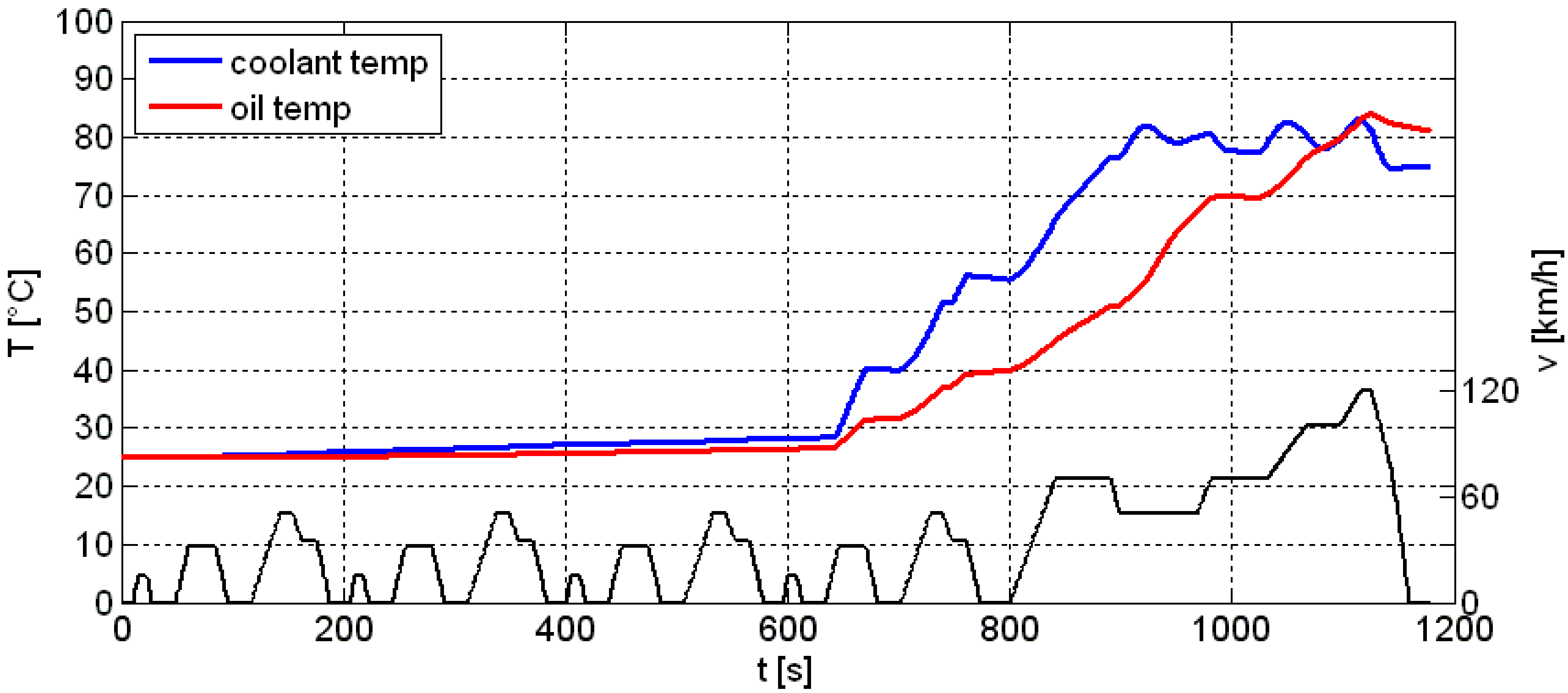
engine pre-heating with electric driving



splitting of cooling circuits after engine start



Utilization of thermal power losses



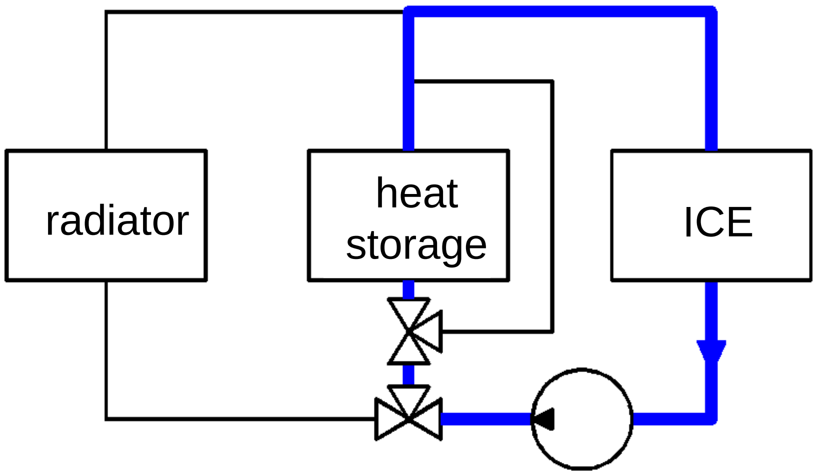
3.1 % fuel saving

but mainly due to the changes in the operating strategy

Content

- Introduction
- Simulation Model
- Fuel Saving Potential
- Thermal Management Concepts
  - Utilization of Thermal Power Losses
  - Heat Storage
  - Utilization of Exhaust Gas Heat
- Conclusions

Heat Storage for Engine Heating



coolant temperature at vehicle turn off: **80 °C**

ambient temp.: **25 °C**

Loss: **4.5 W**

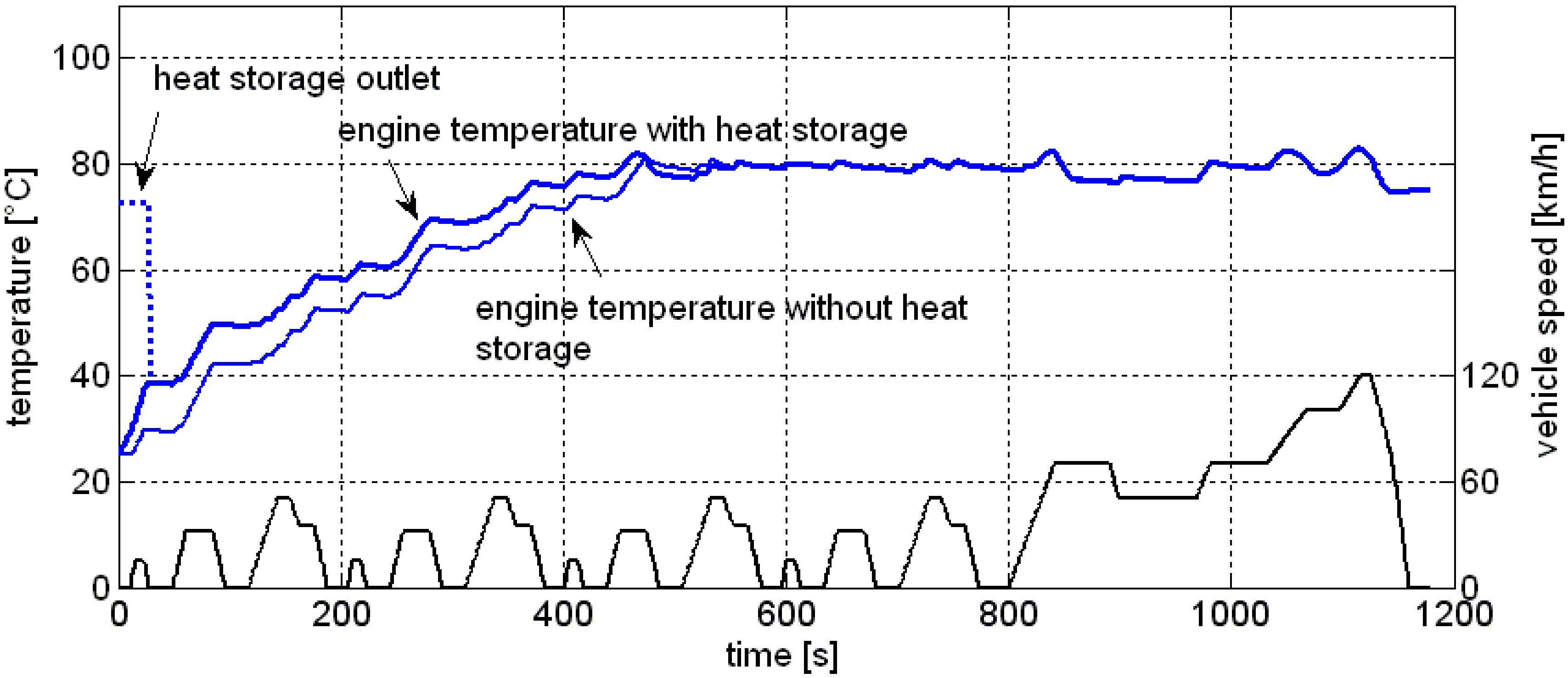
parking duration: **12 h**

coolant temperature in heat storage after 12 h: **72.6 °C**

heat quantity: **190 Wh**

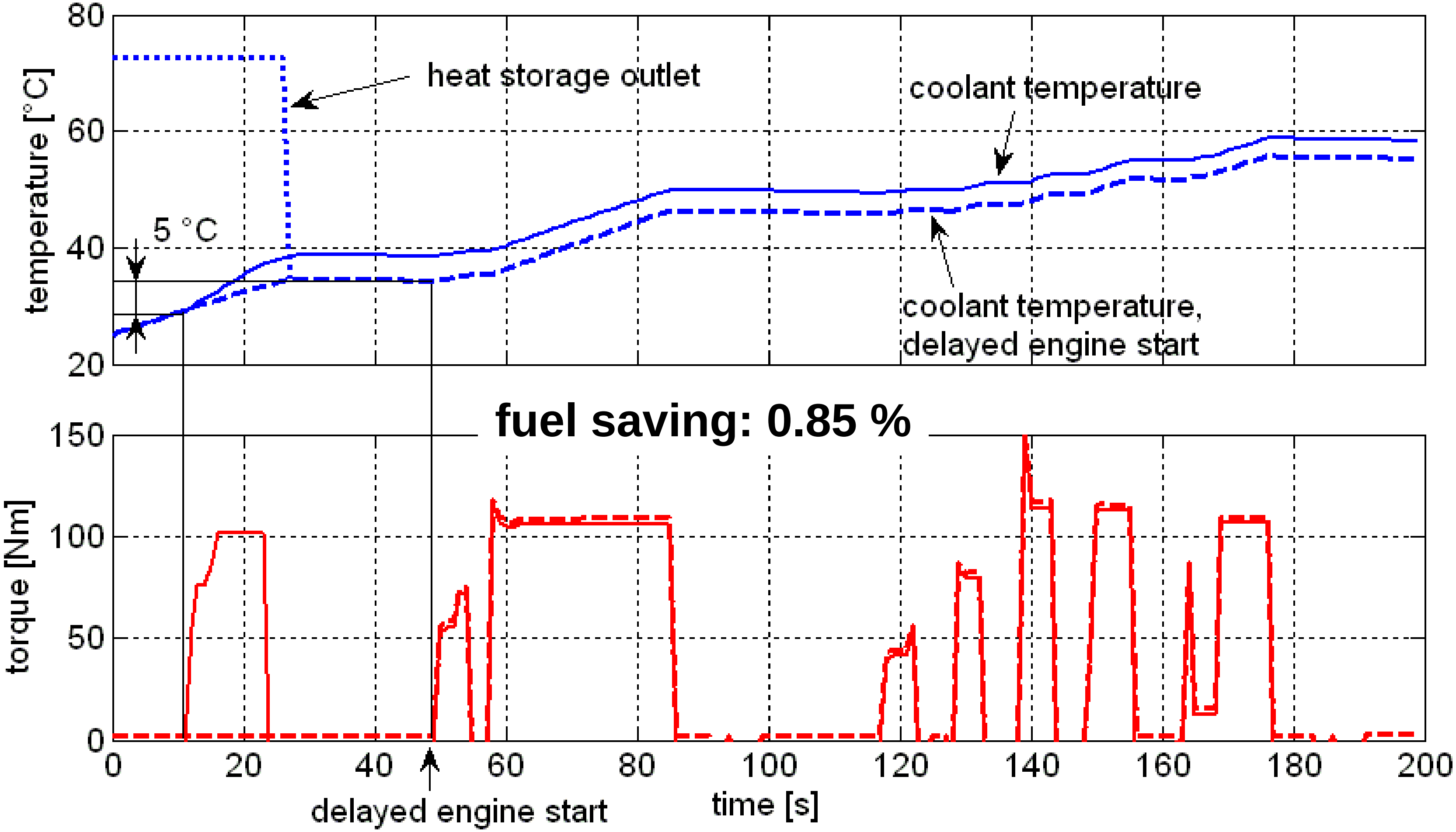
Volume: 7.3 l

Heat Storage for Engine Heating



fuel saving: 0.71 %

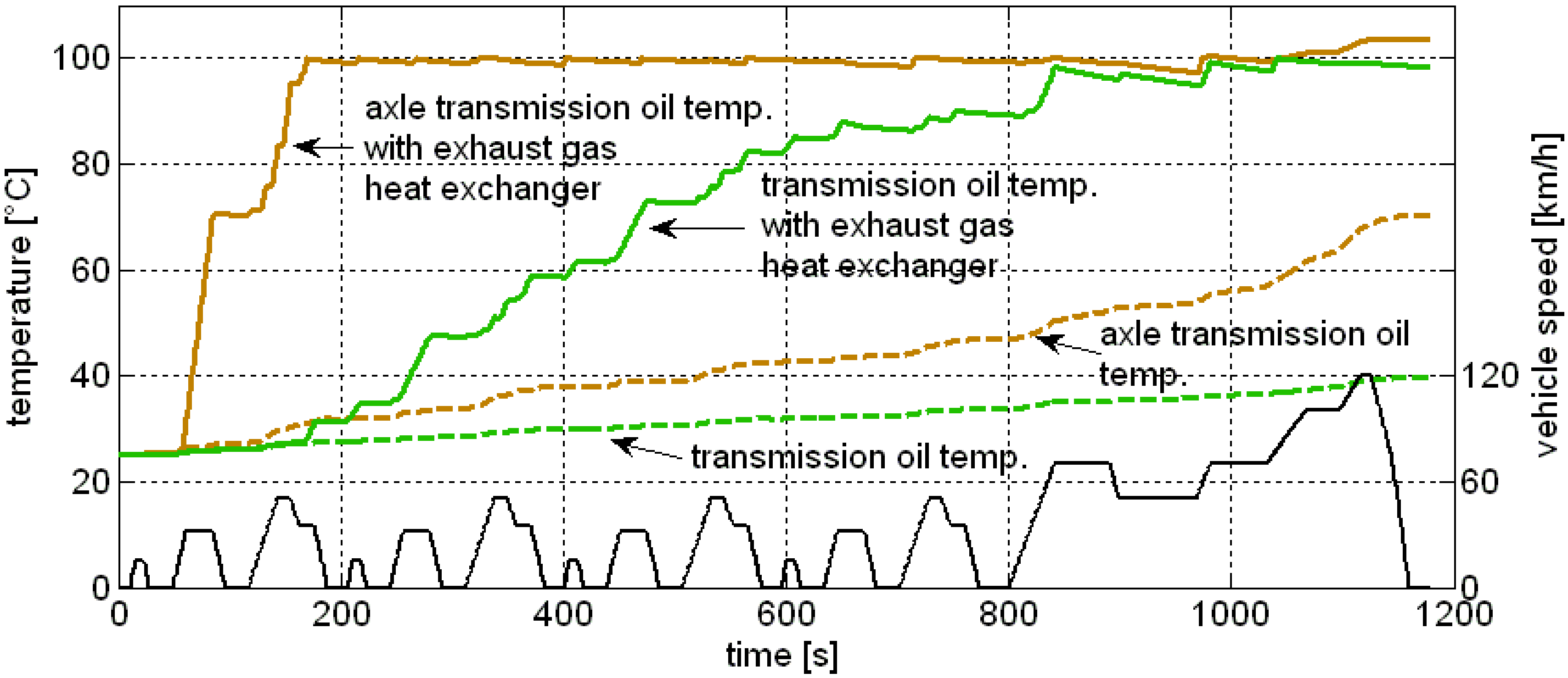
Engine start delayed until heat storage is discharged



fuel saving: 0.85 %

Content

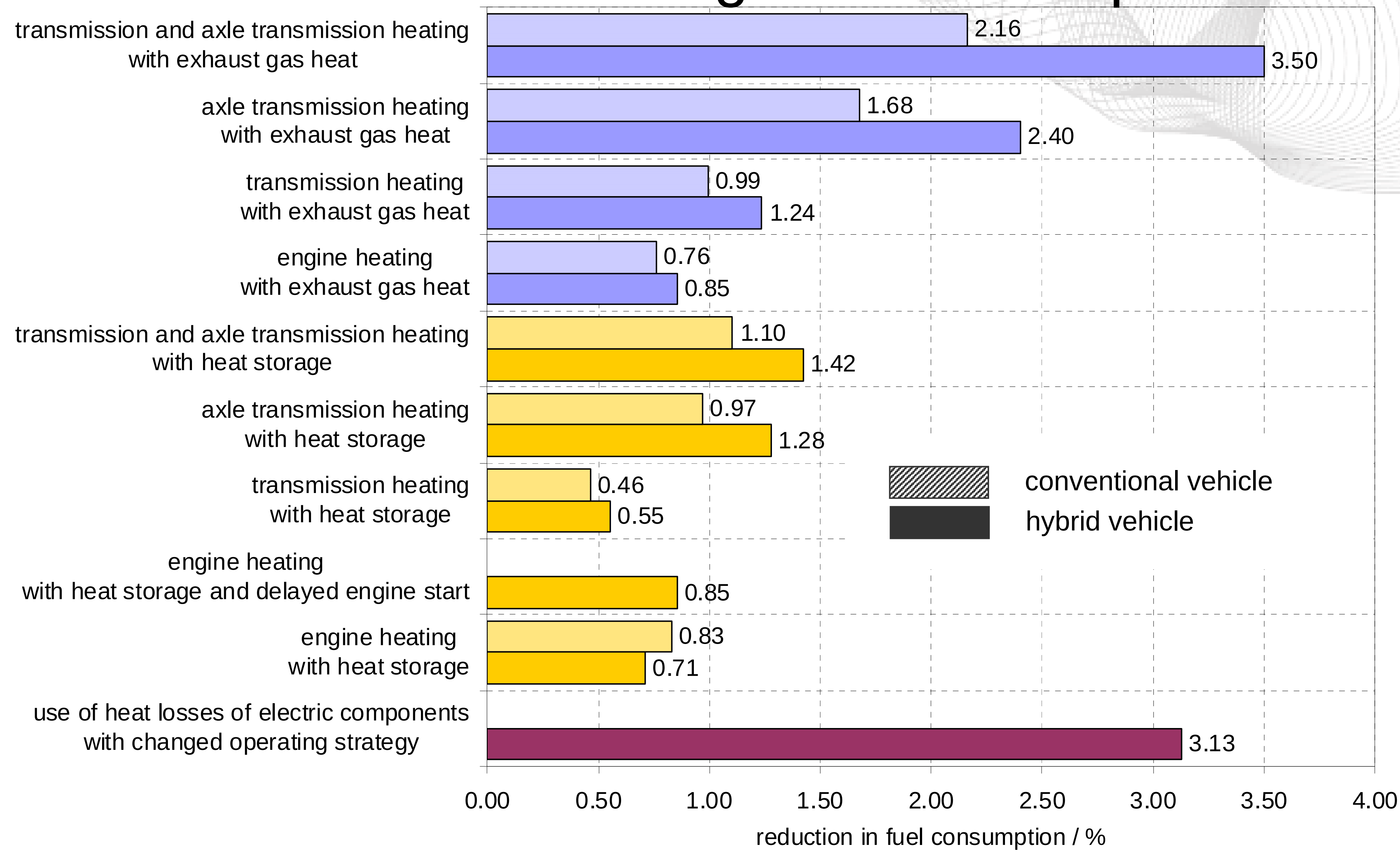
Transmission and axle transmission heating with exhaust gas heat



better transmission efficiency also improves regenerative braking

fuel saving: 3.5 %

Reductions in fuel consumption with different thermal management concepts



Conclusion

- Some means of thermal management can be more efficiently applied in hybrids than in conventional vehicles
- More exhaust gas heat is available in the hybrid
- Thermal management measures targeting on the transmission or axle transmission are improving hybrid specific operational states (regenerative braking, electric driving)
- The efficient electric components provide little heat to be used for a thermal management

contact

Gerhard Lux

Institute for ICE and Automotive Engineering

address:	Getreidemarkt 9
	A-1060 Wien
	Austria
tel:	+43-1-58801-31538
fax:	+43-1-58801-31599
web:	www.ivk.tuwien.ac.at
email:	gerhard.lux@ivk.tuwien.ac.at

funded by:

Federal Ministry of Economics and Labour
City of Vienna
Federal State of Lower Austria
Federal State of Styria
Federal State of Vorarlberg

thank you for your attention !!!!!

Partners: