

# Young Researchers Seminar 2009

Torino, Italy, 3 to 5 June 2009

## Reducing Diesel Railcar CO<sub>2</sub>-Emissions by means of Electric Energy Storages

Discussion of Operating Concepts for  
Hybrid Diesel Multiple Units

Holger Dittus



# Introduction – Diesel Multiple Units (DMUs)

- Typical regional DMUs:
  - vMax ~ 140 km/h
  - distance between stations 1 to 10 km
  - diesel engine with electric, hydraulic or hydro-mechanic drive train
  - vehicle weight 90 to 150t
  - ~ 14 % of passenger train km in Germany



Source: [www.vias-online.de](http://www.vias-online.de)



Source: wikipedia

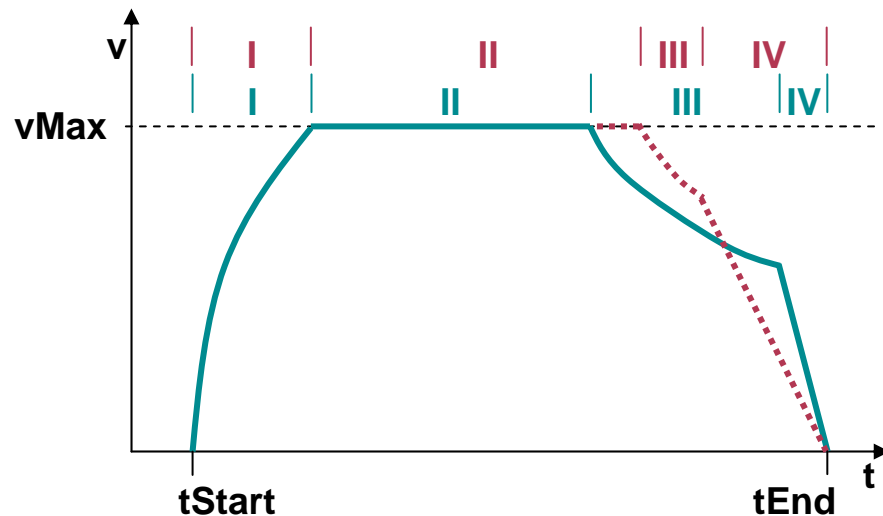
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# Introduction – Driving Style in Regional Traffic

- Basic strategy for energy efficient driving:
  - accelerate as fast as possible
  - drive with constant speed → “cruising”
  - roll out without traction power → “coasting”
  - brake to still stand with high deceleration rate



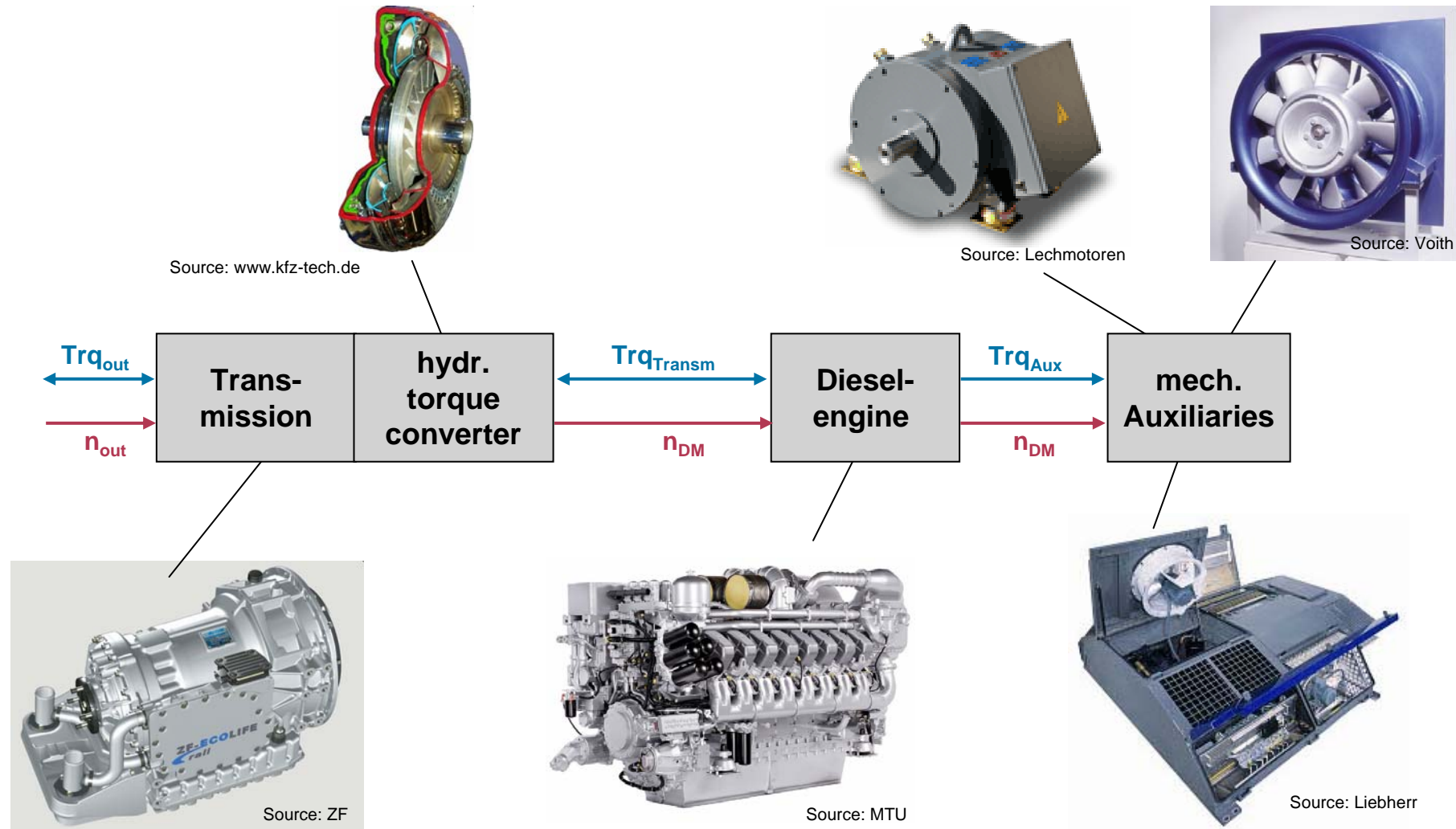
- I - Acceleration phase
- II - Cruising phase
- III - Coasting phase
- IV - Braking phase

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# Hydro-mechanical Drive Train

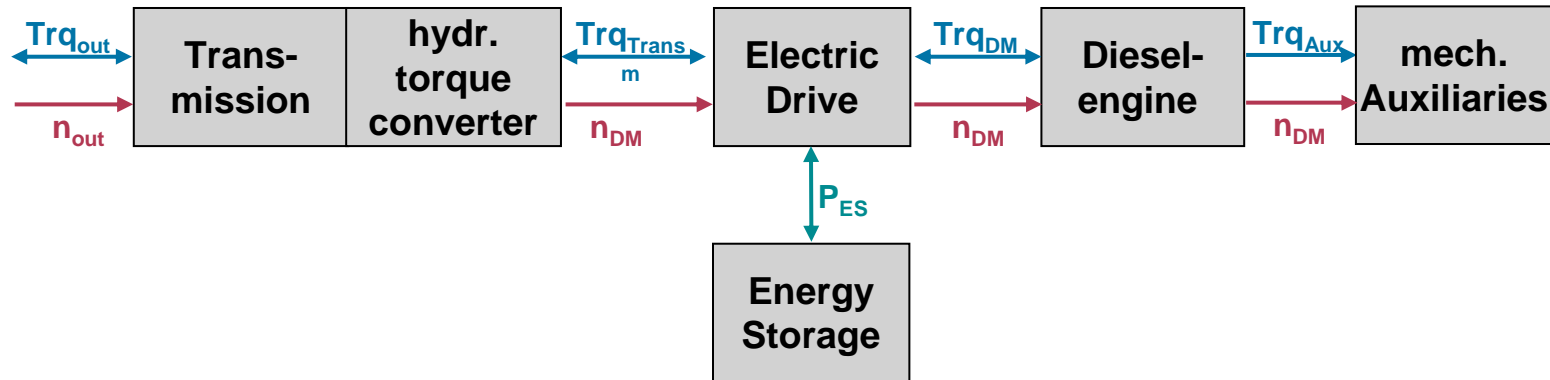


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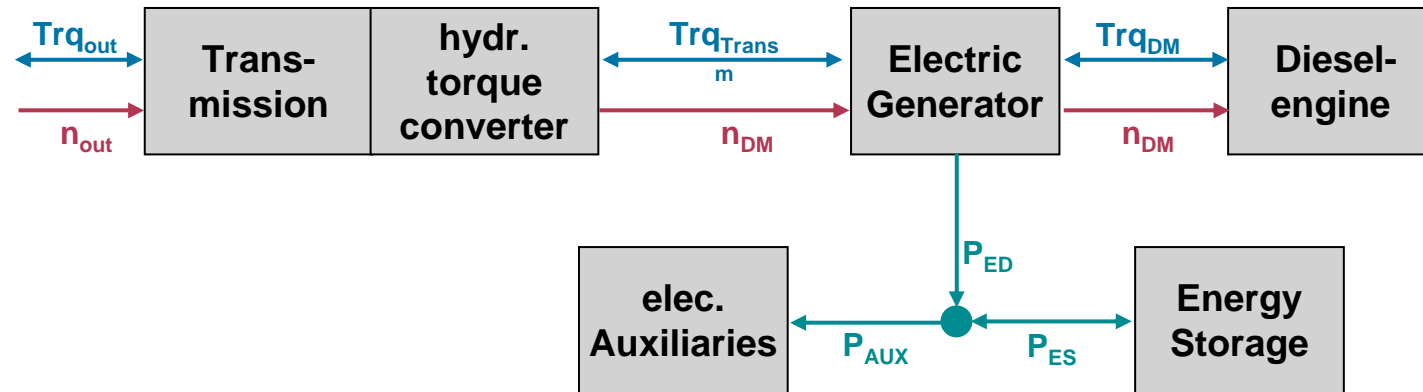


# Hybrid DMU Concept 2



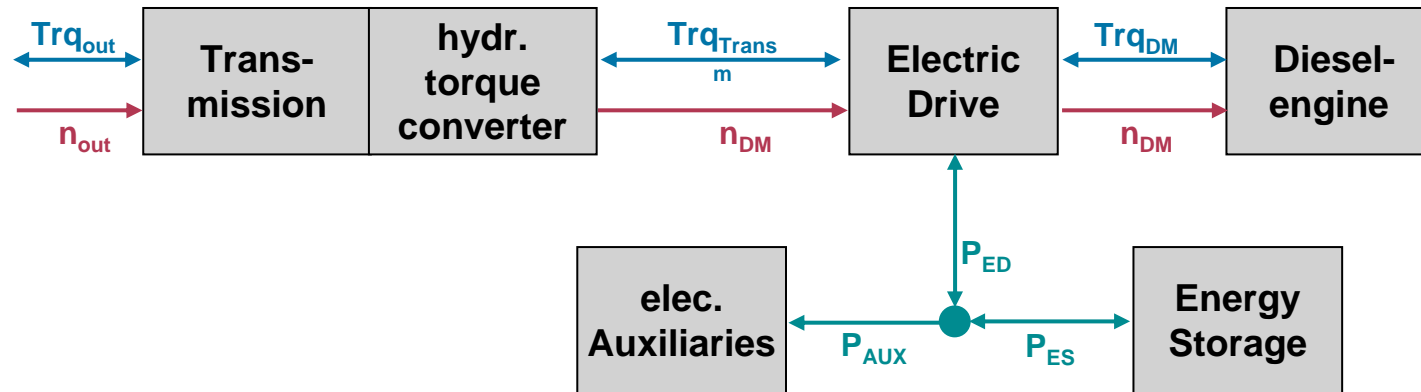
- Characteristics of concept 2:
  - Strategy: provide traction support
  - brake energy recuperation
  - mechanically powered auxiliaries

# Hybrid DMU Concept 1



- Characteristics of concept 1:
  - Strategy: shut down diesel during station stops to avoid inefficient operating points, no traction support
  - brake energy recuperation
  - no emissions & noise within station area
  - electrically powered auxiliaries

# Hybrid DMU Concept 3



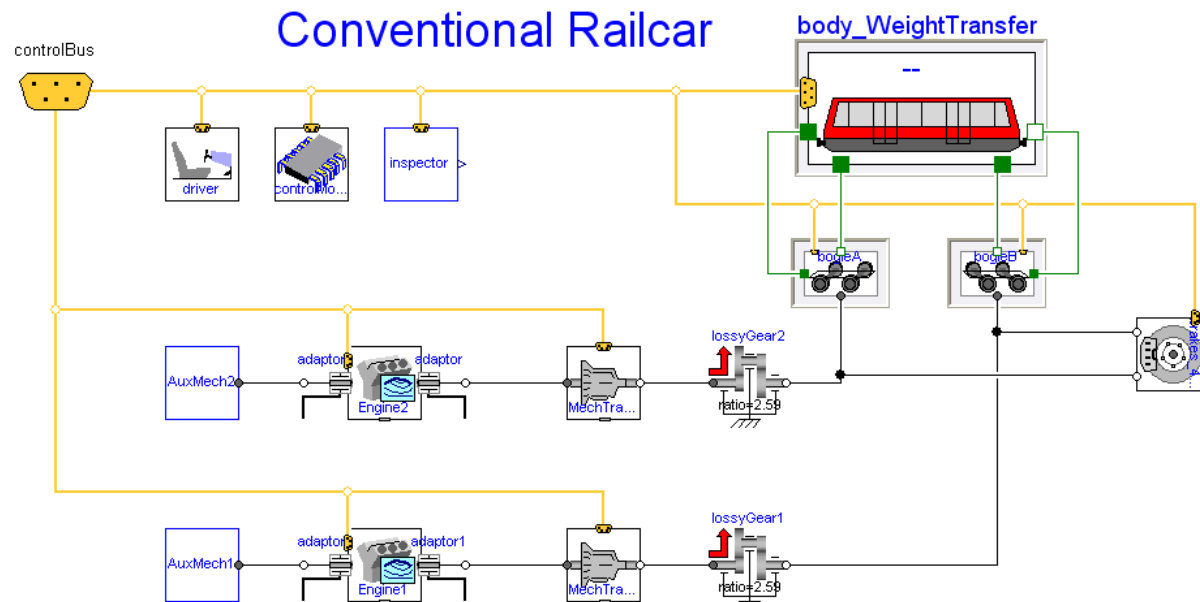
- Characteristics of concept 3:
  - Strategy: shut down diesel engine during station stops, provide traction support
  - brake energy recuperation
  - no emissions & noise within station area
  - electrically powered auxiliaries

# Questions

- Which concept achieves lowest CO<sub>2</sub>-emissions?
- Is energy efficient driving style appropriate to hybrid DMUs? Which influence has the deceleration rate?
- How does electric drive power affect recuperated energy & CO<sub>2</sub>-reduction?
- Where do the reductions result from?

# Simulation Input Parameters

- DMU mass conventional 96 t, hybrid 102 t (+ 6 t for electric drive & storage)
- diesel engine 560 kW, 3200 Nm per power pack
- electric drive, power ratings: 150, 300, 450 kW (1000, 2000, 3000 Nm)
- constant mechanic / electric auxiliary load 45 kW per power pack
- stop time in stations 60s, distance between stations 5 & 10 km, flat track
- max. velocity 100, 120 & 140 km/h



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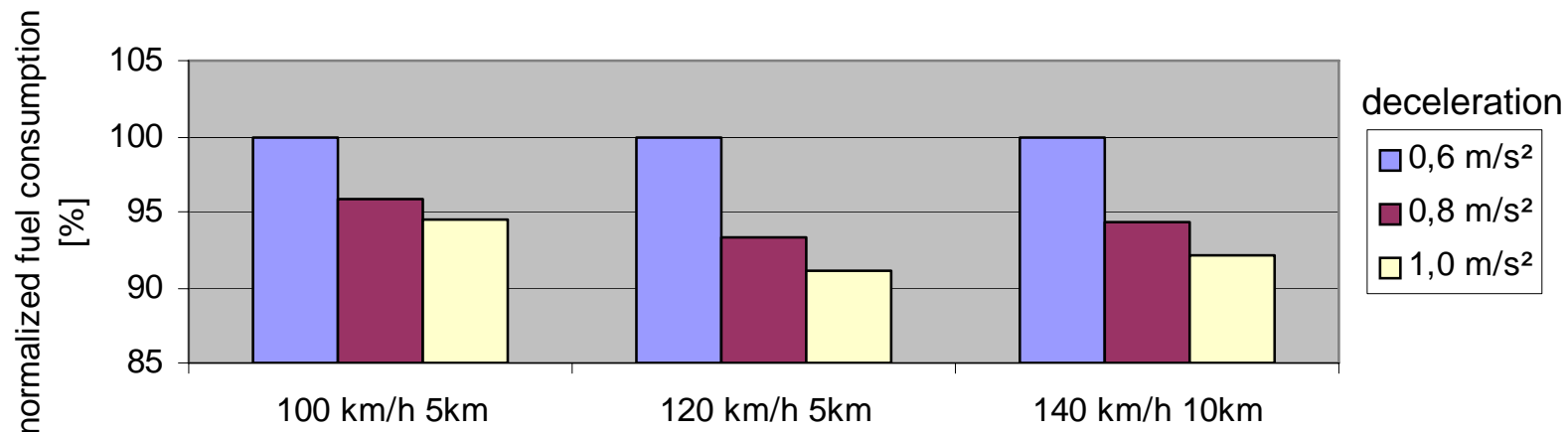
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# Simulation Results

- Energy efficient driving style
  - Conventional DMU

Conventional DMU	
Distance:	5,10 km
Max. Velocity:	100, 120, 140 km/h
Mass:	102 t

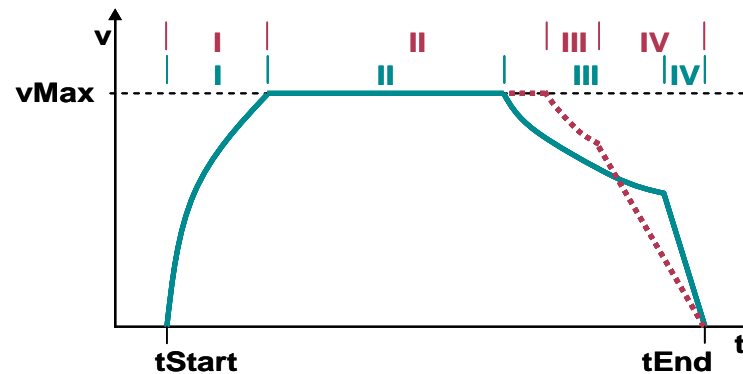
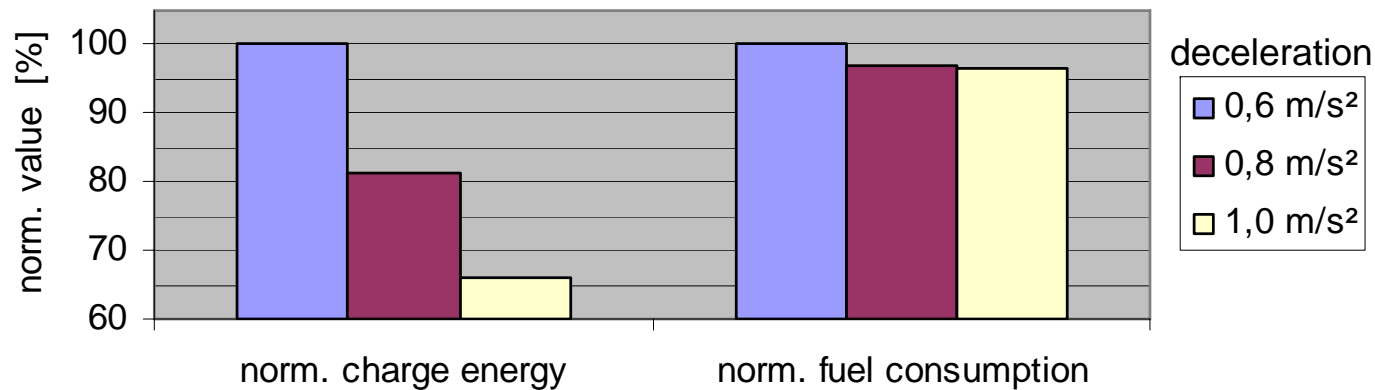


- high deceleration rate increases fuel & CO<sub>2</sub>-savings
- savings up to 9 % at high deceleration rate

# Simulation Results

- Energy efficient driving style
  - Hybrid DMU Concept 2

Hybrid DMU Concept 2	
Distance:	5 km
Max. Velocity:	140 km/h
Mass:	102 t
Electric drive power:	2 x 450 kW



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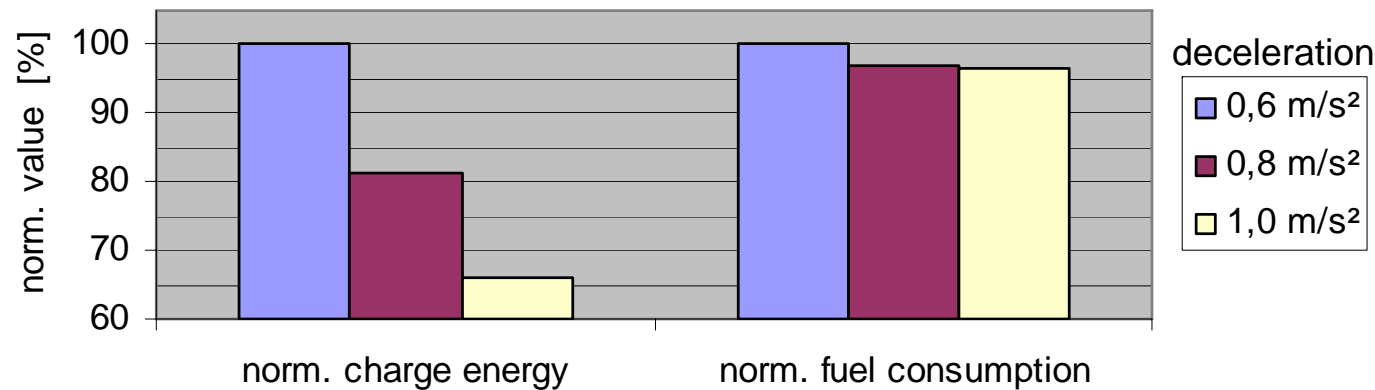
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# Simulation Results

- Energy efficient driving style
  - Hybrid DMU Concept 2

Hybrid DMU Concept 2	
Distance:	5 km
Max. Velocity:	140 km/h
Mass:	102 t
Electric drive power:	2 x 450 kW



→ 34 % less energy recuperated at 1 m/s<sup>2</sup>

→ 3 % reduction of CO<sub>2</sub> & fuel consumption

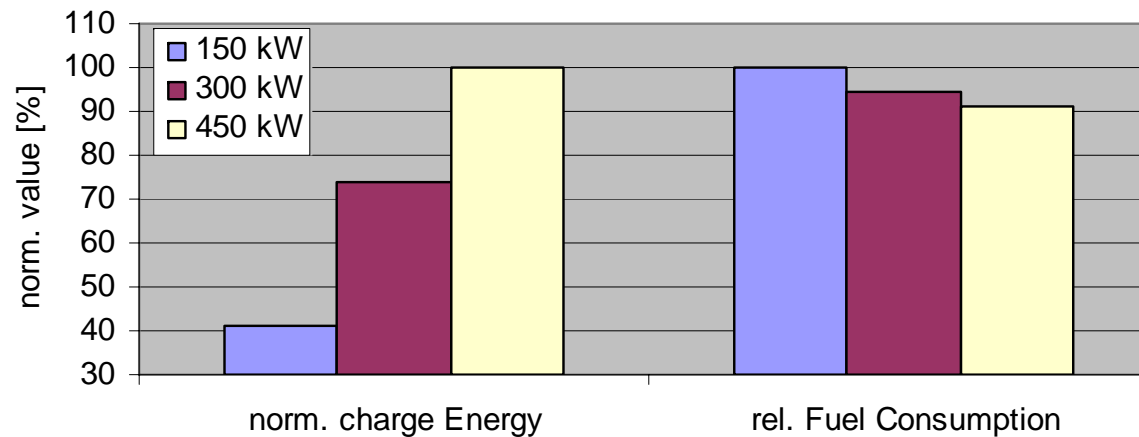
→ smaller effect of deceleration rate variation

➔ Driving Style adaptation to hybrid DMU needed!

# Simulation Results

- Effect of electric drive power
  - Hybrid DMU Concept 2

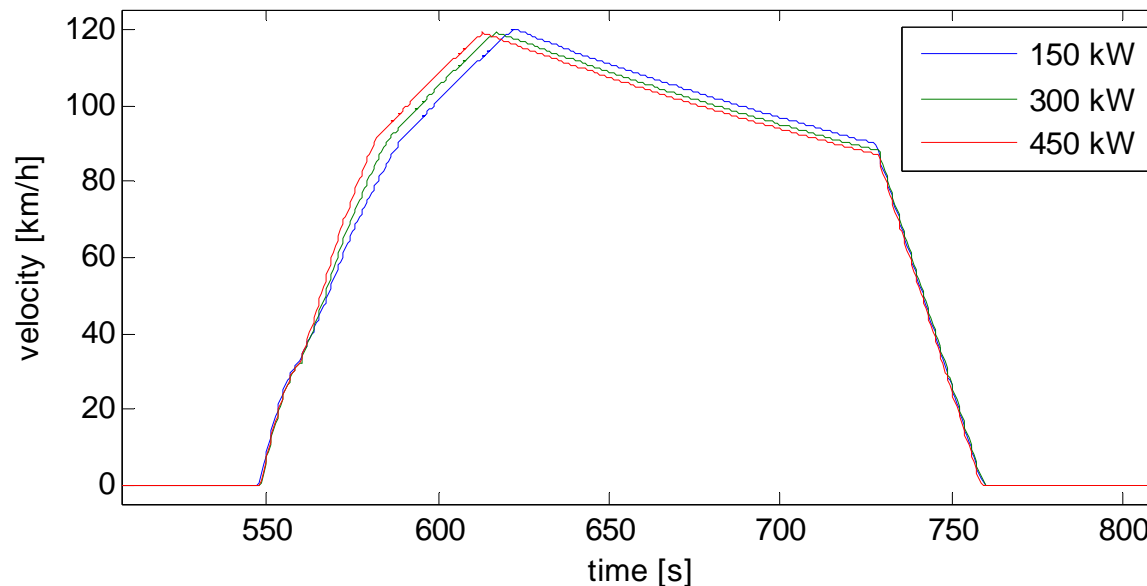
Hybrid DMU Concept 2	
Distance:	5 km
Max. Velocity:	120 km/h
Mass:	102 t
Deceleration rate:	0.8 m/s <sup>2</sup>



- More power increases amount of recuperated energy
- CO<sub>2</sub> & fuel savings increase with drive power

# Simulation Results

- Effect of electric drive power
  - Where do the CO<sub>2</sub> and fuel savings result from?

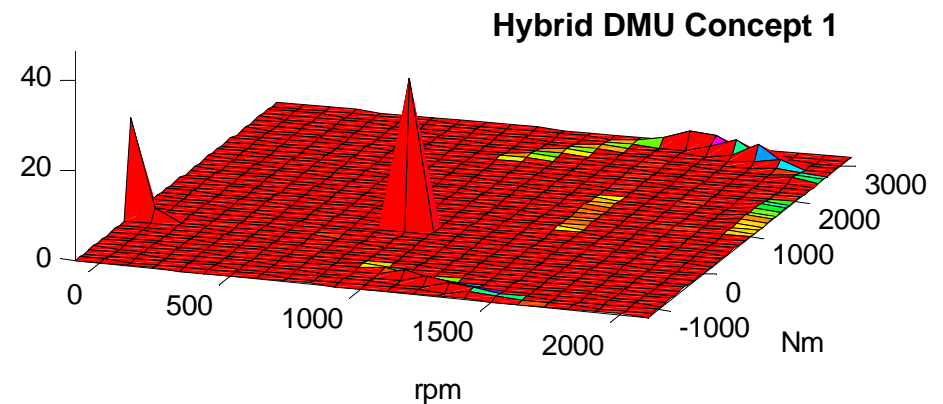
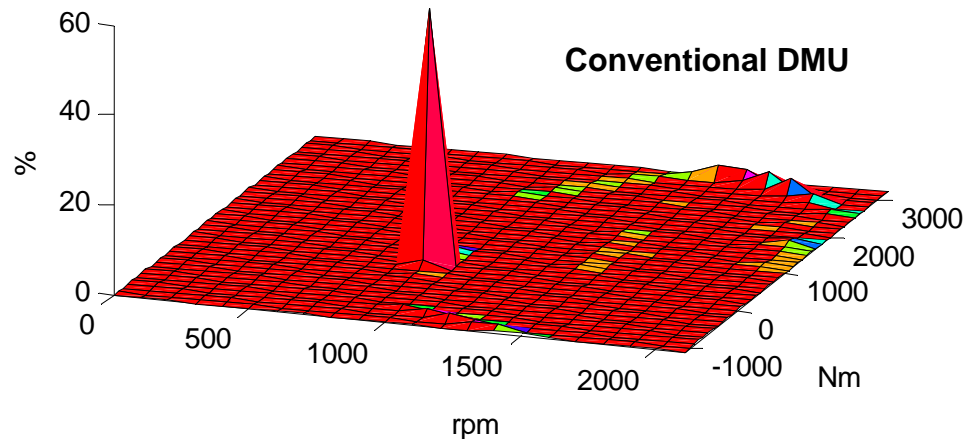


Additional traction power → shorter acceleration phase  
→ extended coasting phase

# Simulation Results

- Engine stop within stations
  - diesel engine operating points

Hybrid DMU Concept 1	
Distance:	5 km
Max. Velocity:	120 km/h
Mass:	102 t
Electric drive power	2 x 450 kW
Deceleration rate:	0.8 m/s <sup>2</sup>



→ Engine stop avoids > 25% of idle time compared to conventional DMU

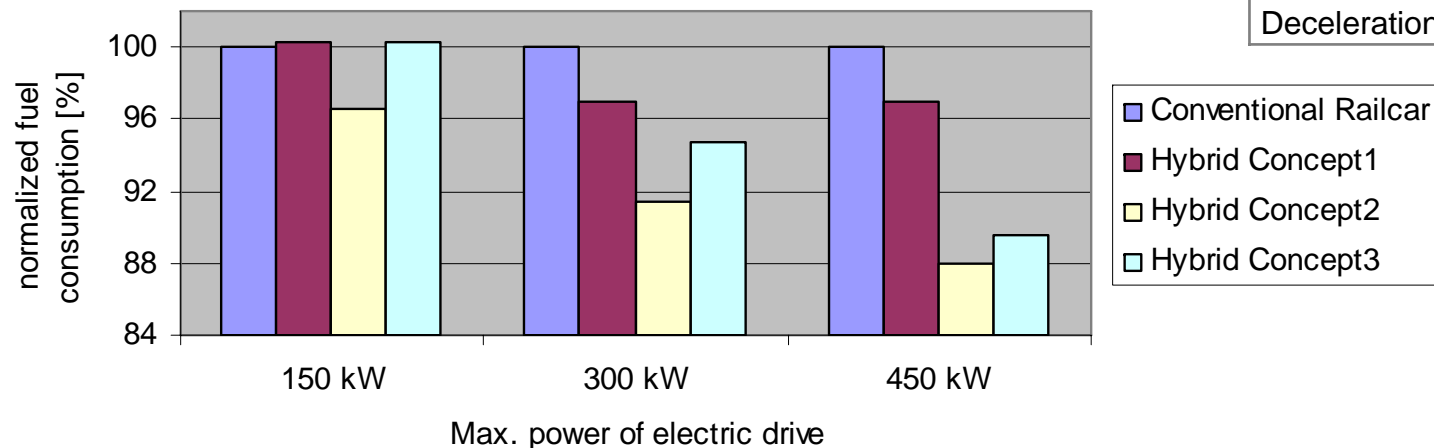
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# Simulation Results

- Comparison of Concepts



Hybrid DMU Concepts	
Distance:	5 km
Max. Velocity:	120 km/h
Mass:	102 t
Deceleration rate:	0.8 m/s <sup>2</sup>

- Concept 1: limited CO<sub>2</sub>-savings
- Concept 2: CO<sub>2</sub> & fuel savings up to 12 %
- Concept 3: Combination of zero emission in stations and overall CO<sub>2</sub>-reduction up to 10 %

# Summary – Concept 1

- Pros:
  - + local zero emission operation in station area
  - + CO<sub>2</sub> and fuel savings up to 4 %
- Cons:
  - maximum CO<sub>2</sub>-reduction & fuel savings predefined by stop time & auxiliary load → capped benefit
  - minimum electric drive power required to provide benefit
  - changes in system layout (electric auxiliaries)

## Summary – Concept 2

- Pros:
  - + best in CO<sub>2</sub> & fuel savings (up to 12 %)
  - + benefit even with small electric drive power
  - + add-on system, no changes in auxiliary system
  - + similar storage power when charging / discharging
  - + recuperates more brake energy than other concepts
- Cons:
  - local emissions in station area
  - highest storage capacity needed

## Summary – Concept 3

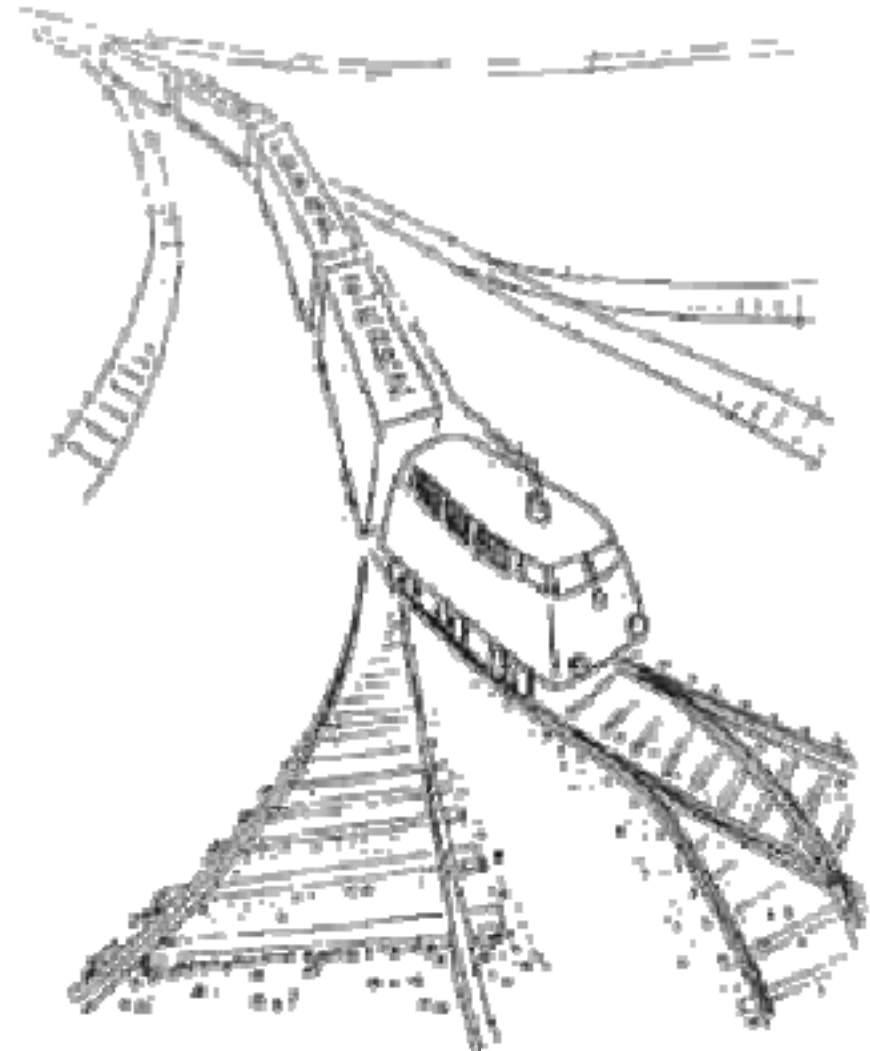
- Pros:
  - + local zero emission operation in station area
  - + CO2 & fuel savings up to 10 %
  - + additional electric power provides higher benefit
- Cons:
  - minimum electric drive power required to provide benefit
  - changes in system layout (electric auxiliaries)

# Conclusions

- Traction support provides best CO2-reduction & least complex system layout
- Engine stop functionality requires sufficient electric drive power & changes in system layout
- Combined hybrid system provides good CO2-reduction and local zero emission
- Adaptation of energy efficient driving style to characteristics of hybrid DMUs recommended

# Conclusions

**Thank you for your  
attention!**



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