How far can you get without a friction brake on rear axle?
The RABBIT project

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OUTLINE

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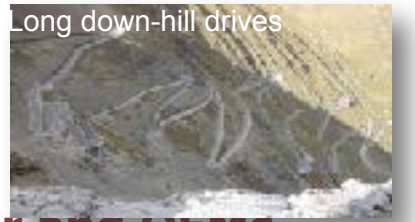
The RABBIT Project Vision
Regenerative braking

- **Utilization of braking energy in all operating conditions**
  - Full/empty, cold/hot battery
  - Long downhill drives



- **Fulfillment of requirements by legislator, end customer and OEMs**
  - No longer braking distance
  - No limitation in availability

Today‘s regenerative brake systems do not fulfill these requirements

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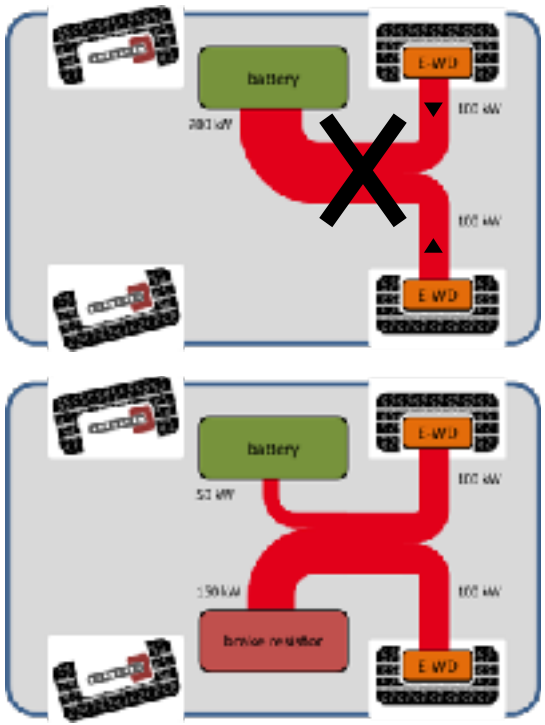
The RABBIT Project Concept
Regenerative braking

- Replace the mechanical friction brake on the rear axle with regenerative braking by 2 inwheel hub motors
- Maximum deceleration on the rear axle of **0.3 g**
- Realization of a 0.3 g deceleration through recuperation at the rear axle leads to a max. electric power of **200 kW**
- The battery system can't be charged at **10 C** or more at any given ambient conditions, SOC and SOH

→ Redundant energy sink needed



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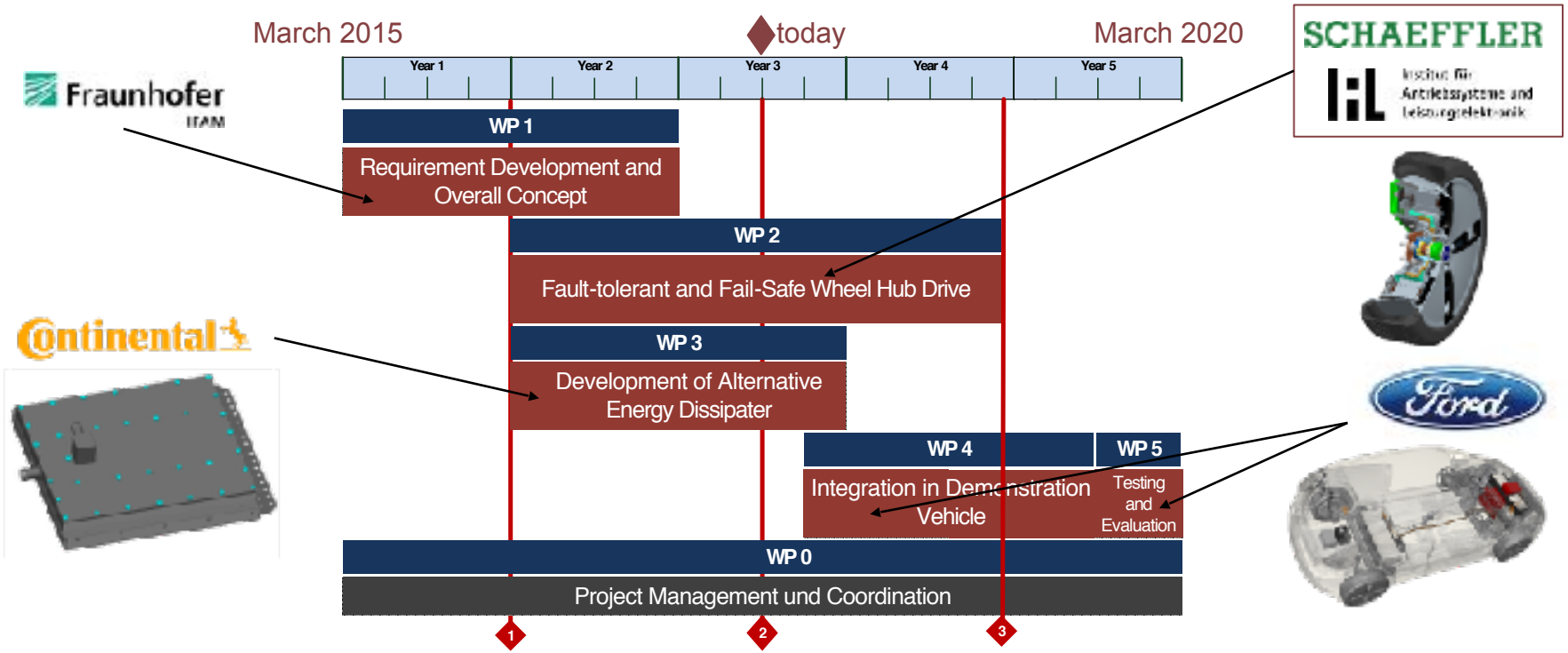
The RABBIT Project Consortium
Timeline & Work Packages



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Description	Effect on	Min. deceleration	Actuator
Operating brake	Front and rear axle	5,76 m/s²	Brake pedal
Auxiliary brake	Front and rear axle	2,44 m/s²	Brake pedal
Parking brake	Typical rear axle	1,5 m/s²	Push-button or lever

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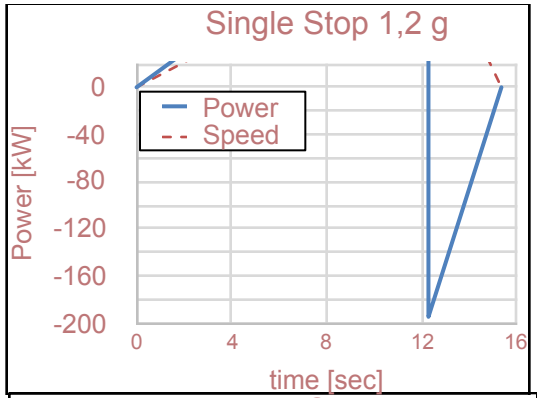

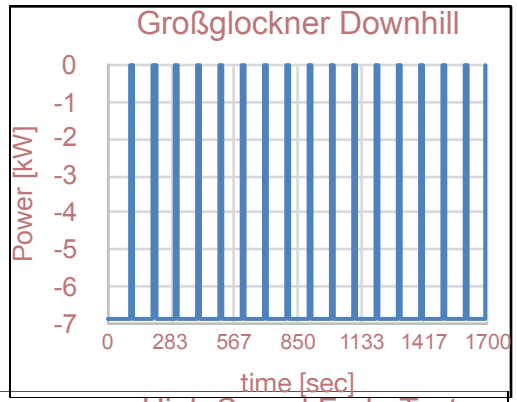

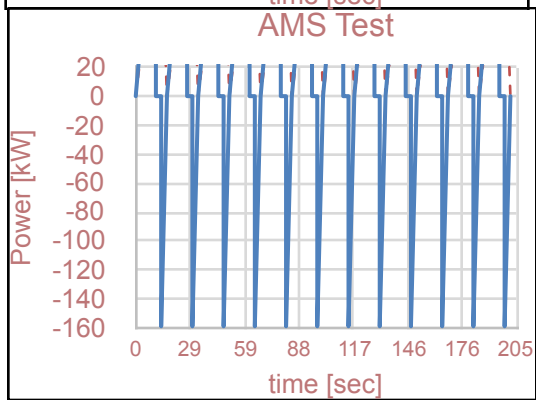

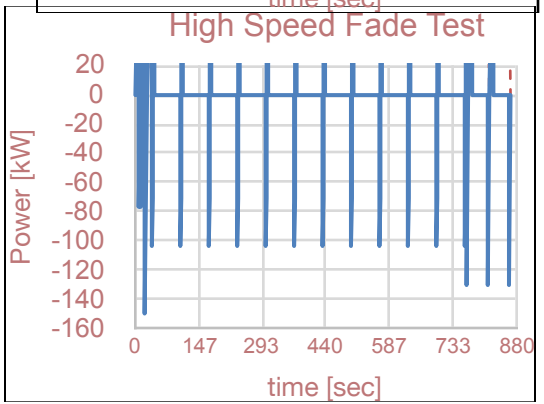

- Different vehicle test cases have to be fulfilled
- Redundant energy sink (electric heater) converts the electric energy into heat
- The electric heater shall handle peak and continious power

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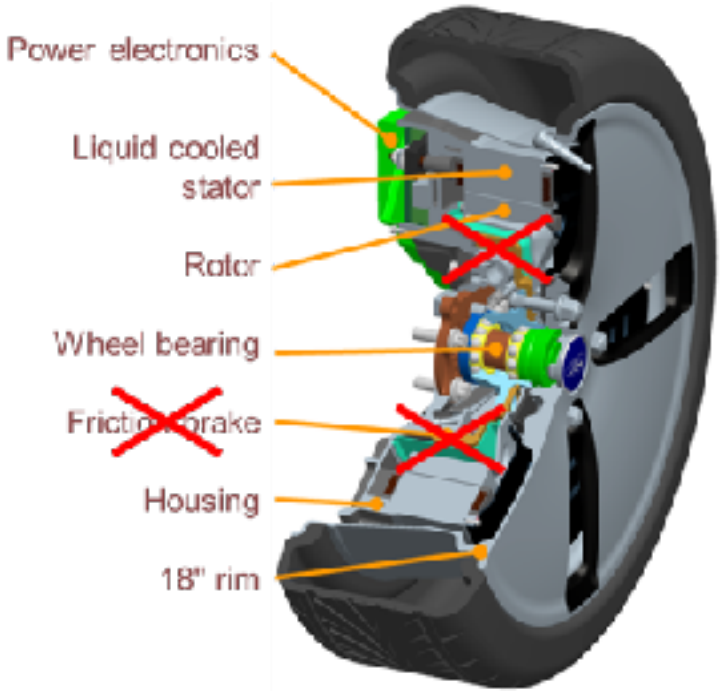
Electric Wheel Hub Drives do not need a mechanical brake

- Sufficient peak torque (at the rear axle) for all braking conditions incl. emergency braking
- Individual wheel hub drive can fulfill safety relevant brake functions (i.e. ABS, ESP)
- Omitting the mechanical brakes leads to technical and economic advantages



Source: Schaeffler

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Torque gradient of the Wheel Hub Drives

Simulation Results at different Voltages

Originally HV battery voltage

Increased DC-link voltage

→ To fullfill the specification a increased DC-Link voltage is needed

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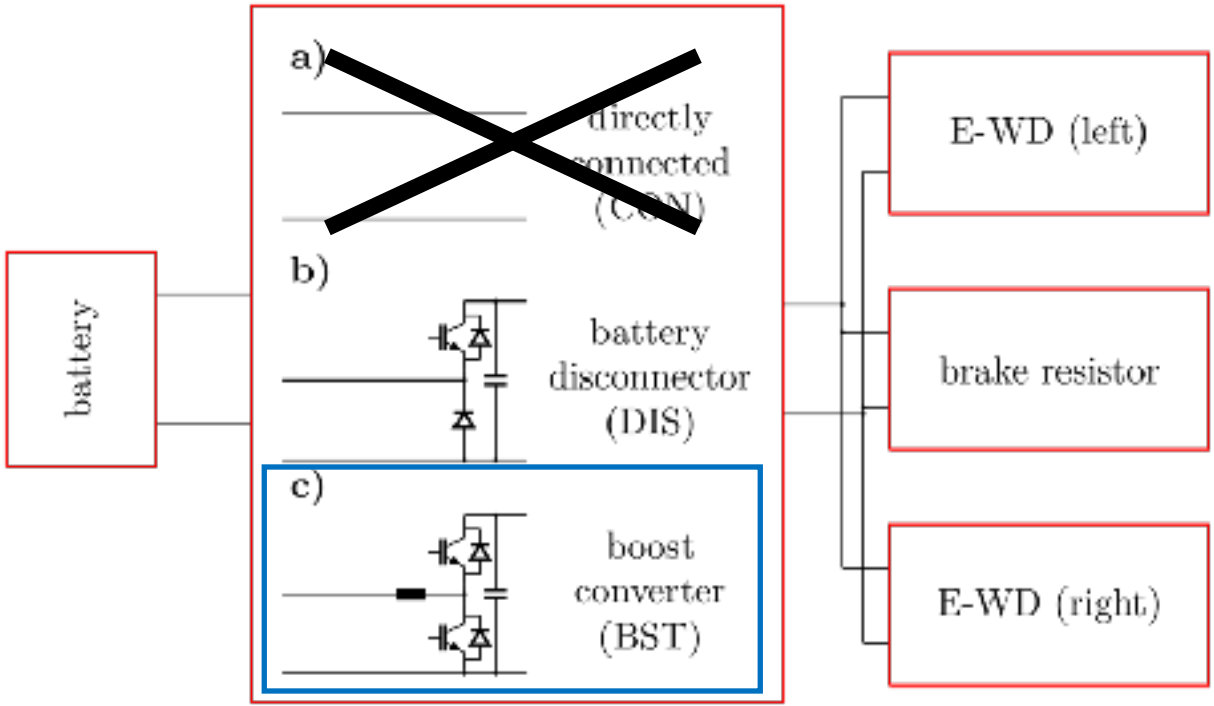
HV Architecture
Schematic View



- Directly connected architecture don't fulfill requirement
- Boost converter enables more functionality compared to battery disconnector

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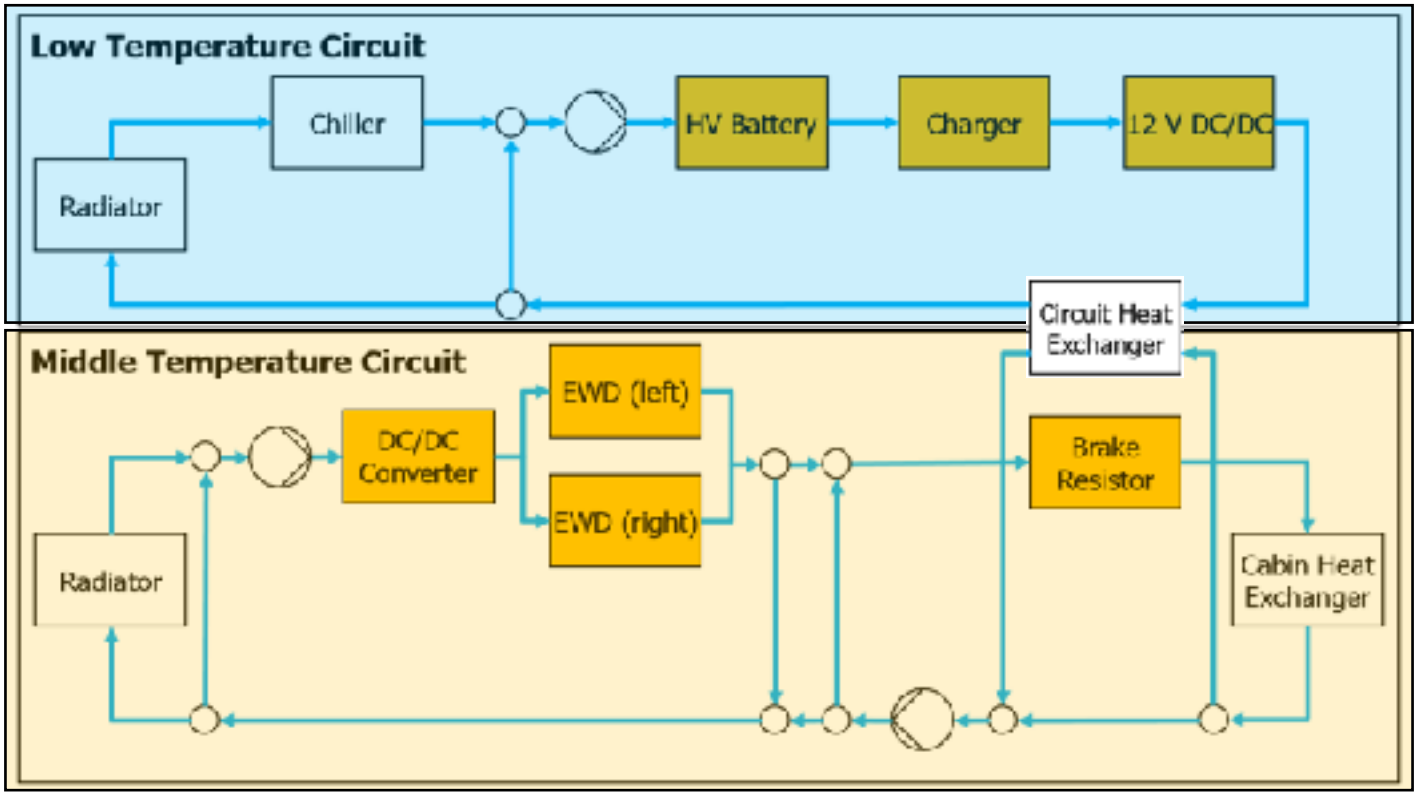
Thermal Architecture
Schematic View



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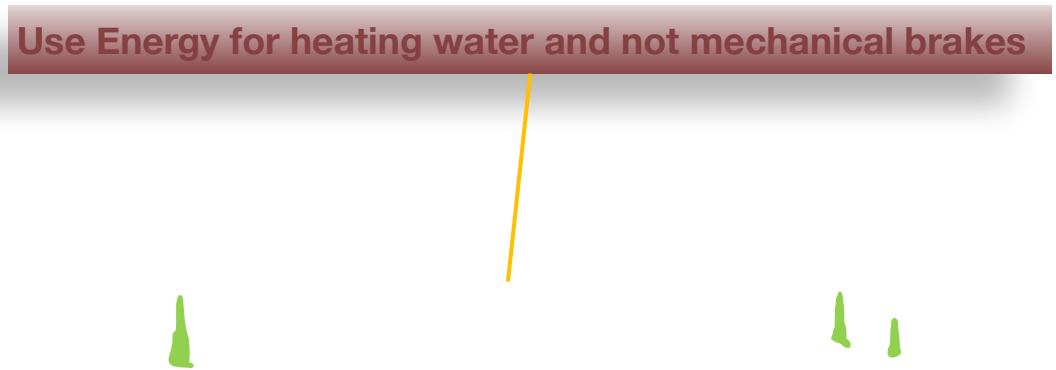
Electro thermal recuperation (ETR)
Potential to increase the range



Electro Thermal Recuperation:

- Brake resistor recuperates waste brake energy as heat
- Intelligent control strategy and thermal system inertia used for energy efficient heating
- Potential for energy saving 5-10 %

Source: J.Lieb et. al.„Potential of an electric brake resistor to increase the efficiency of electric vehicles", EVS27 Barcelona November 17-20 2013

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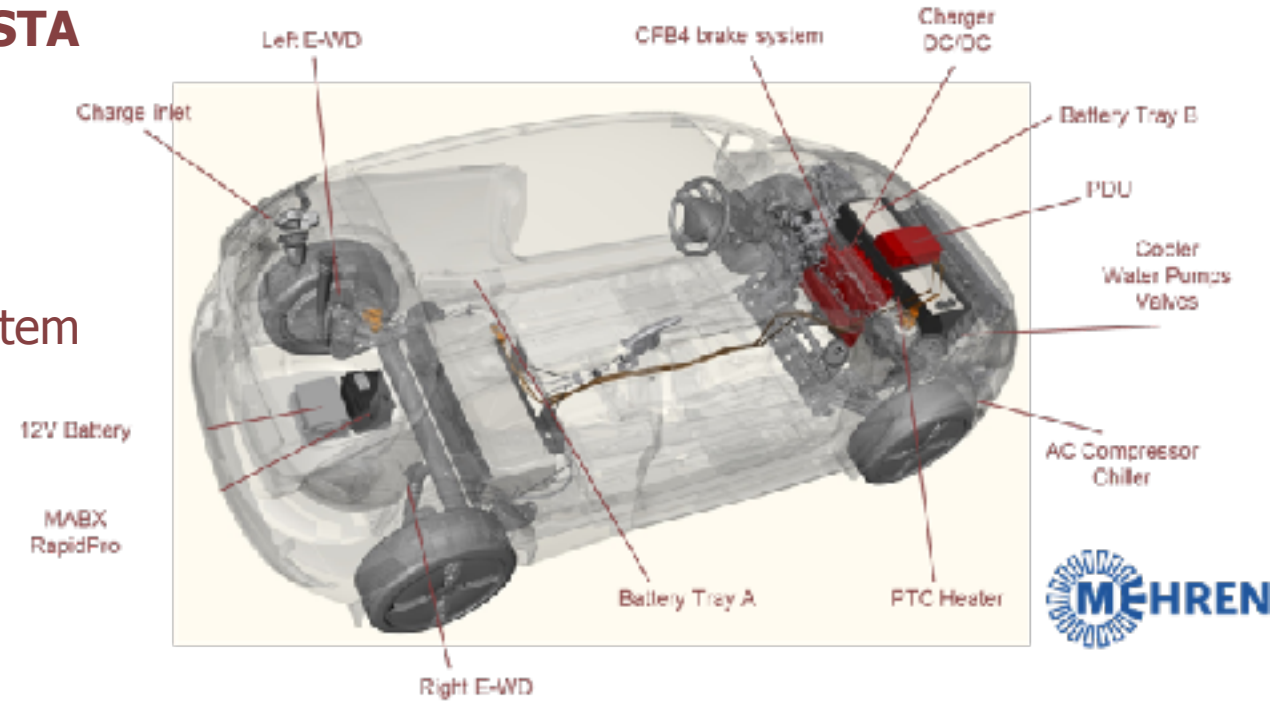
MEHREN demonstrator based on a Ford FIESTA

- v_{max} = 130 km/h
- $m_{laden,max}$ = 1.700 kg
- 18.8 kWh battery system



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OUTLINE

1 Motivation & Project Description

2 Vehicle Requirements

3 System Concept

4 Conclusion and Outlook

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CONCLUSION

RABBIT allows…

- … for the first time the **substitution of a mechanical friction brake** by an electrical system on the rear axle
- … the reliable provision of a brake torque by a **fault tolerant E-Wheel Drive with an Alternative Energy Dissipater**
- … the range extension by **electro-thermal recuperation**
- … **testing different operating scenarios** with a demonstrator vehicle to investigate and assess both **safety and customer acceptance** (passenger comfort / handling quality) aspects

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