The possibility for energy regeneration by electrification in Swedish car driving

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Regenerative braking is a valuable advantage of hybrid and electric cars

- How valuable?
  - How much energy is lost through braking?
  - Power levels needed in regeneration?

The results are compared with standardized test cycles (NEDC and the suggested WLTP)

The database including real world drive cycles

- 430 privately driven Swedish cars
- Car model 2002 and younger
- GPS installed for 1-2 months
- Logging was conducted in 2.5 Hz
- March 2010-Sept 2012

Detailed speed, acceleration and altitude profiles of 430 cars!

Not only for a typical trip but for all trips during 30 to 60 days!

The vehicle model

$$P(t) = P_{\text{acceleration}}(t) + P_{\text{air drag}}(t) + P_{\text{rolling resistance}}(t) + P_{\text{grade}}(t)$$

$$P_{\text{acceleration}}(t) = m \cdot a(t) \cdot v(t)$$

$$P_{\text{air drag}}(t) = \frac{1}{2}\rho_a \cdot A \cdot C_d \cdot v^3(t)$$

$$P_{\text{rolling resistance}}(t) = c_r \cdot m \cdot g \cdot \cos(\alpha(t)) \cdot v(t)$$

$$P_{\text{grade}}(t) = m \cdot g \cdot \sin(\alpha(t)) \cdot v(t)$$

Vehicle parameters	
Mass of car	1500 kg
Air resistance (C_d*A)	0.7 m^2
Rolling resistance c_r	0.01

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The vehicle model

Dissipative power demand, energy lost as heat

$$P(t) = P_{acceleration}(t) + P_{air\ drag}(t) + P_{rolling\ resistance}(t) + P_{grade}(t)$$

Conservative power demand, energy can be recovered

$$E_{traction} = E_{air\ drag} + E_{rolling\ resistance} + E_{brake}$$

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E_{brake} is the shit

- E_{brake} is what we are interested in, since this is wasted energy that can be converted to useful energy!

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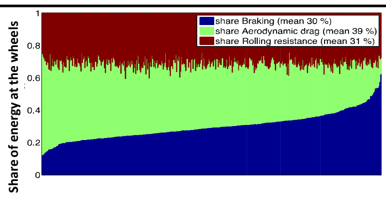
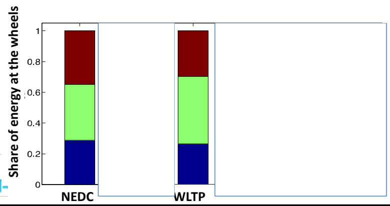
Share of energy used for braking



Do not include altitude data



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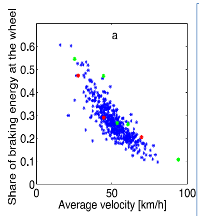
Cumulative energy savings



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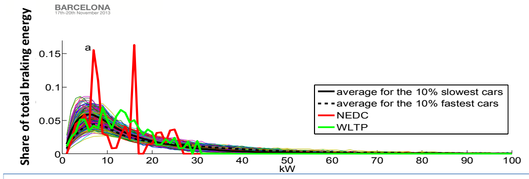
Power need in regeneration



Assumptions, average regeneration potential and savings for the two exemplary drivelines

	BEV	mHEV
Power limit	40 kW	10 kW
Engine braking	-	4.7 kW
Two-way efficiency	0.6	0.5
Driveline efficiency	0.72	0.17
Charger efficiency	0.94	-
Share regen. potential, E_{regpot}/E_{trac}	30% Energy lost through braking (as before)	
Share recoverable energy, E_{rec}/E_{trac}	27% Max 40 kW	5.5% max 10 kW and engine braking
Share reusable energy, E_{reused}/E_{trac}	16% After charging and discharging	2.8%
Yearly savings at the wheels, E_{reused}	510 kWh 10 x more than in the mHEV	51 kWh
Yearly savings at electric outlet/tank, $E_{reused}/\eta_{driveline}$	750 kWh 2.5 x more than in the mHEV	300 kWh
Yearly savings in €	75€ 1.5 x more than in the mHEV	50€

Conclusions

- Data from real world driving (including altitude data) is important to better understand the potential benefits from regeneration

Thank you for listening! **Larshenr@chalmers.se**