



@EVSymposium29

#EVS29

Braking energy recovery potential of electrified vehicles according to their type of use and drivetrain characteristics

F. Badin, F. Raymond, F. Le Berr, A. Frobert : IFP Energies nouvelles, France

The IFPEN Transports Energie Carnot Institute belongs to the French Carnot network (<http://www.instituts-carnot.eu>)

Organized by:



Hosted by:



In Collaboration with:



Platinum Sponsors:

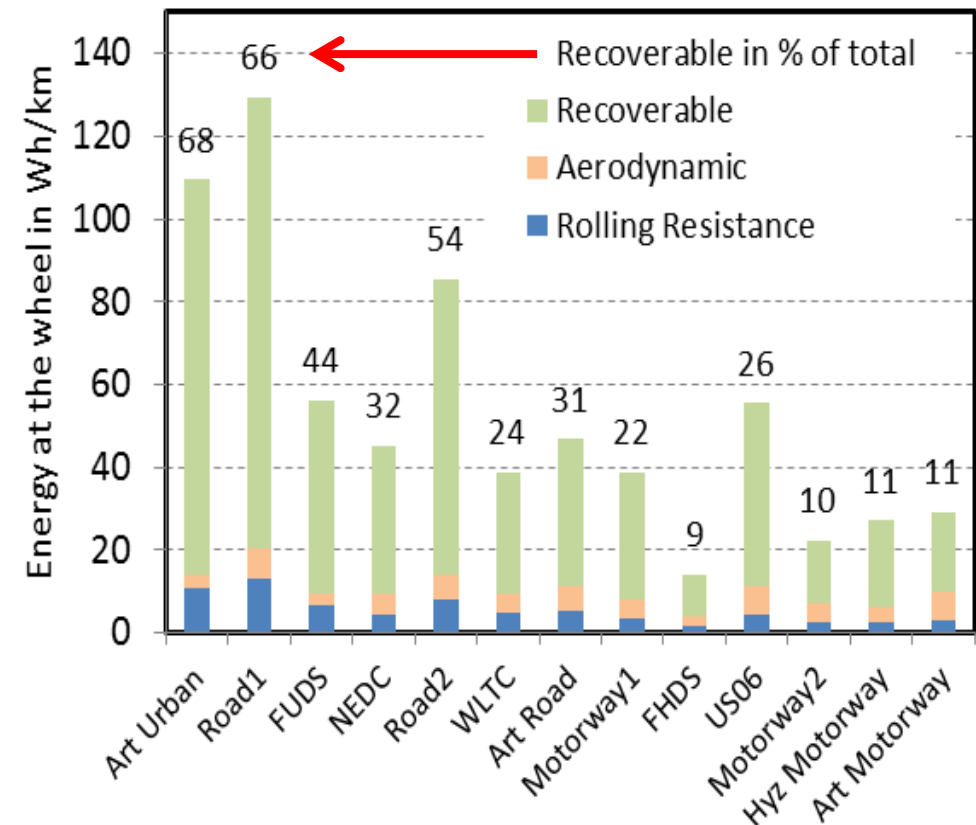
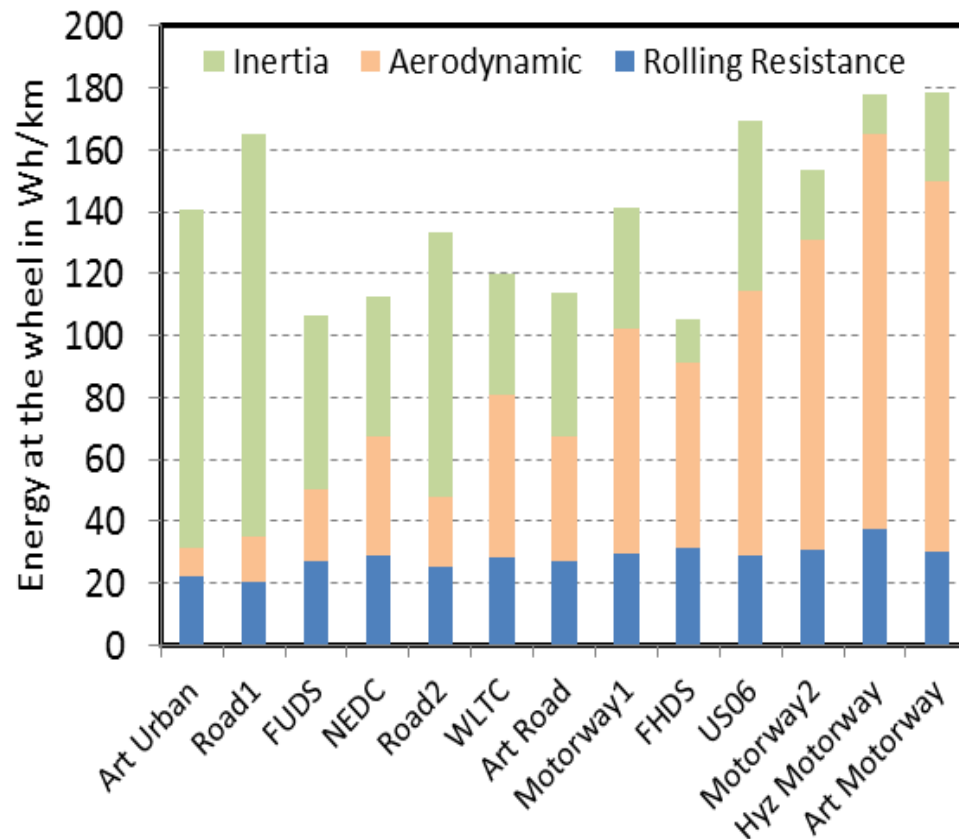


**DRIVE ELECTRIC INNOVATION
PROPULSER L'INNOVATION EN MOBILITÉ ÉLECTRIQUE**

EVS29.ORG

ENERGY RECOVERY POTENTIAL ACCORDING TO DRIVING CONDITION

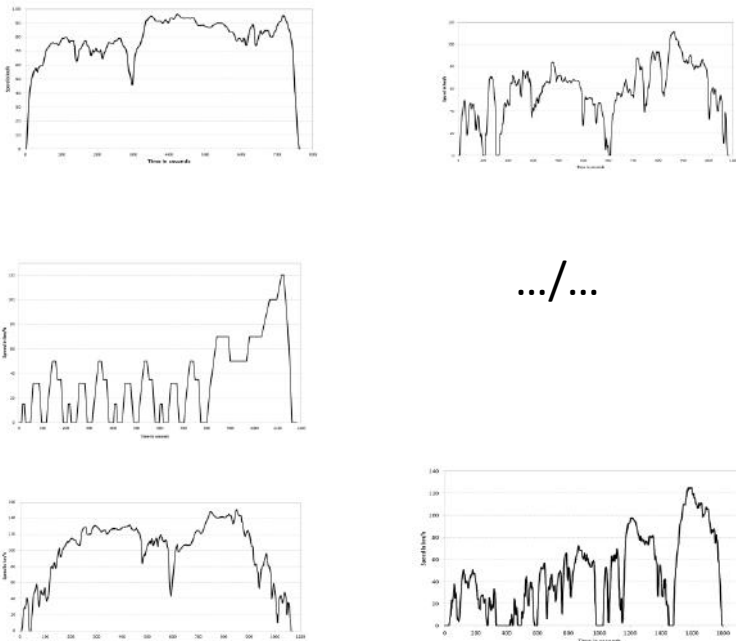
● Energy at vehicle level according to driving schedules



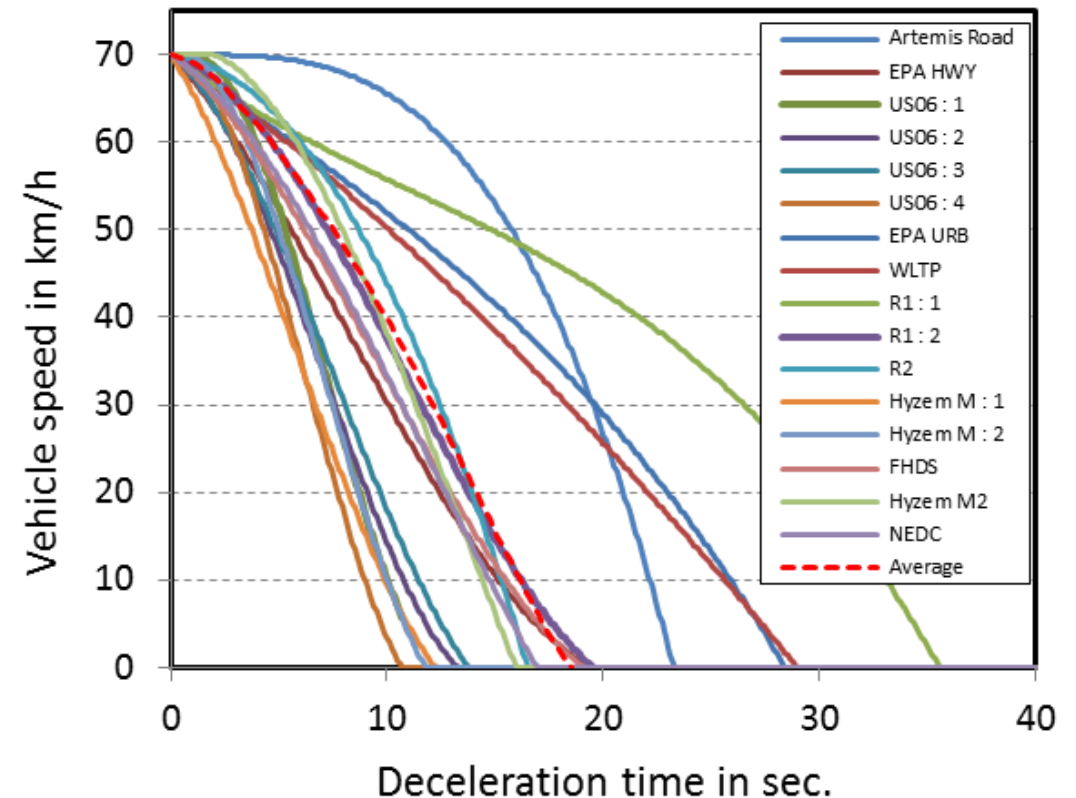
DECELERATION SPEED PROFILES CONSTRUCTION (1/2)

- Two cases considered, 70 and 110 km/h initial speed

- 11 driving patterns

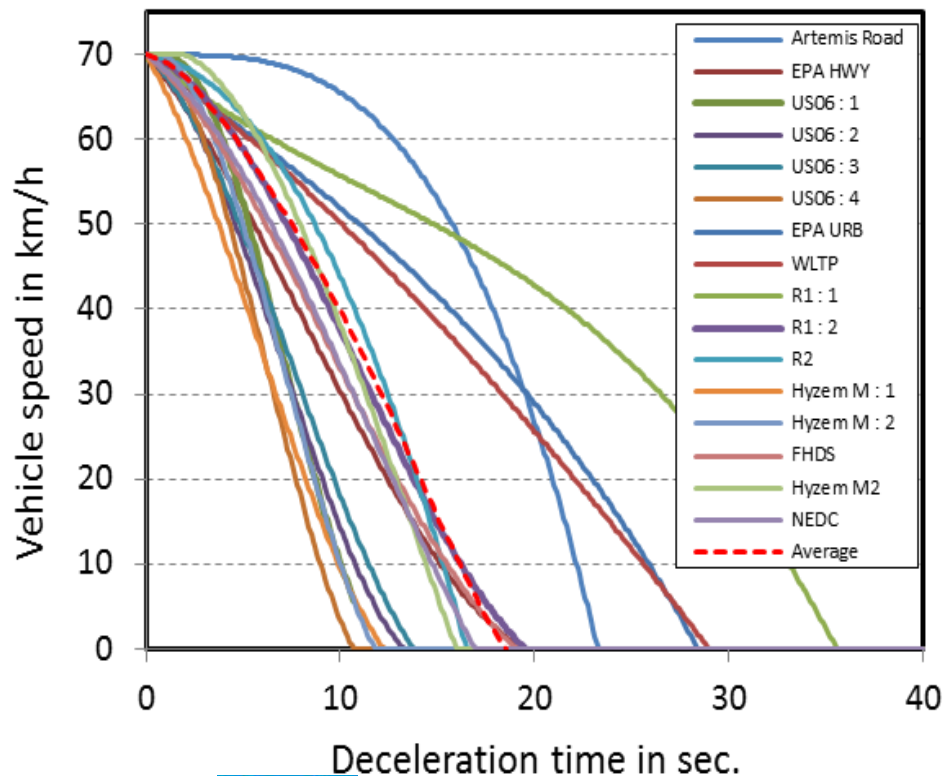


- 16 actual use decelerations from 70 km/h to zero

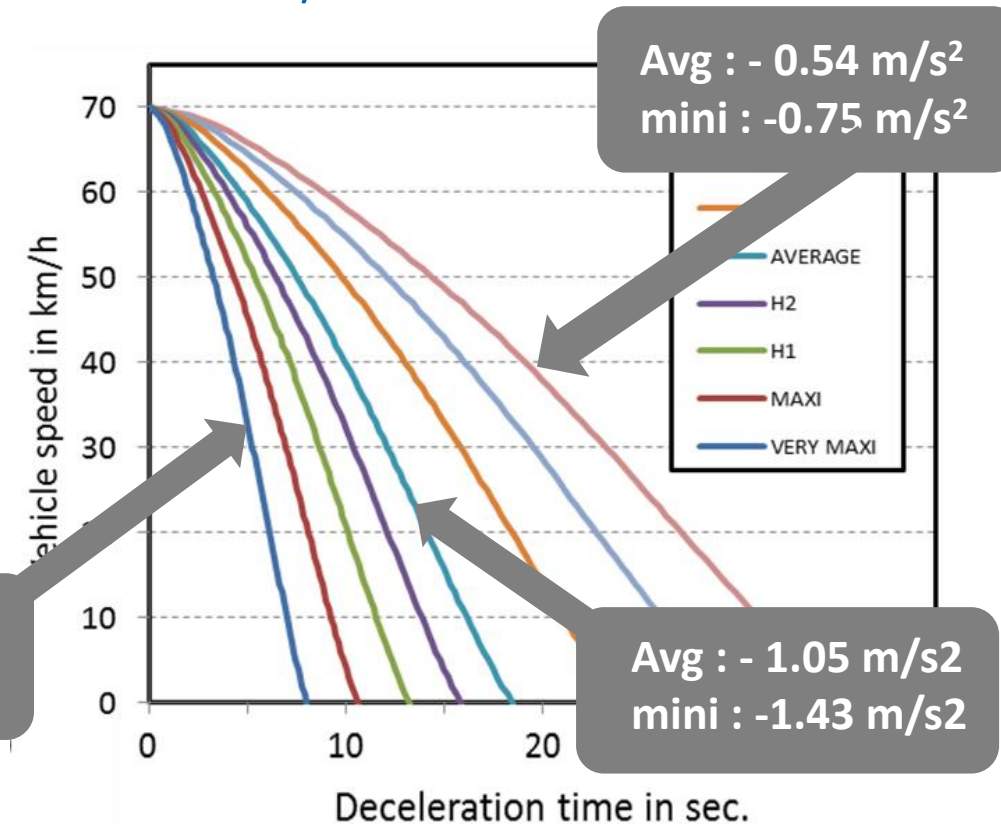


● From actual use patterns to calibrated decelerations (70 km/h case)

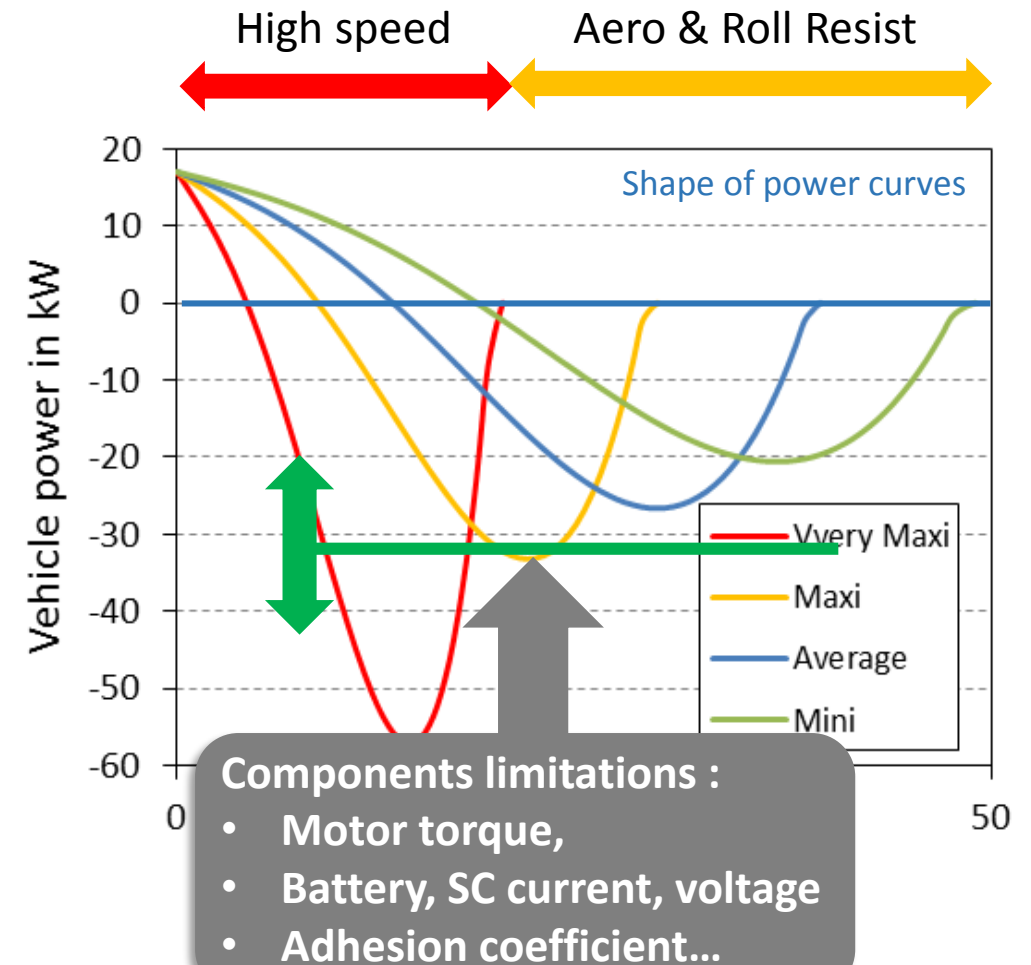
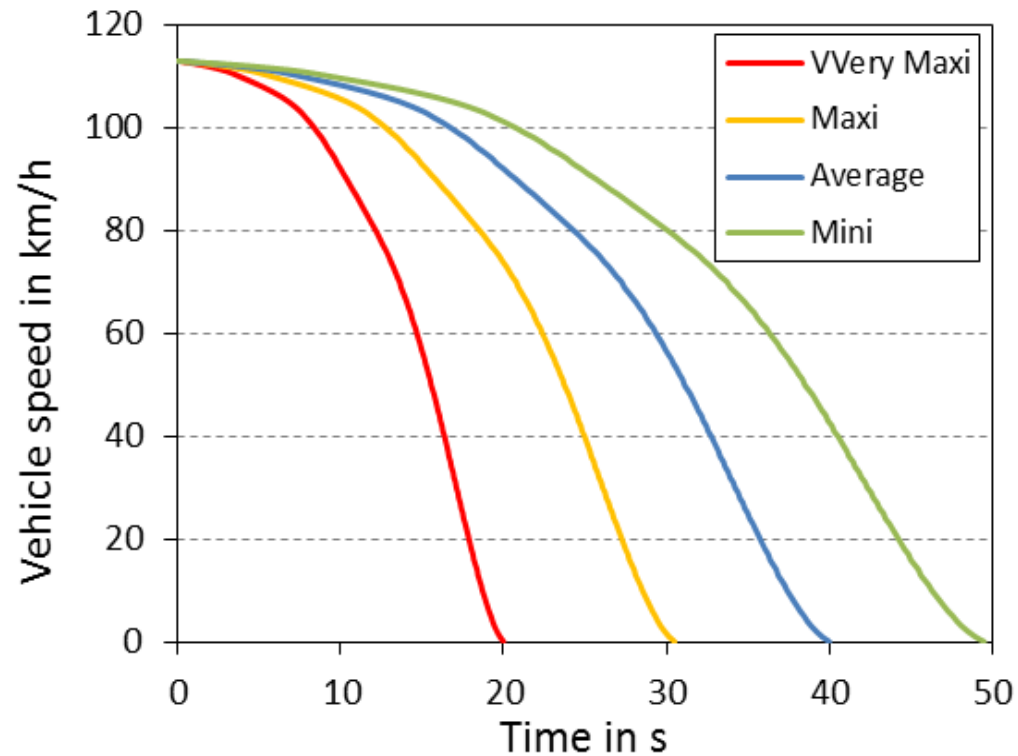
● 16 actual use decelerations from 70 km/h to zero



● 8 calibrated decelerations, from 70 km/h to zero

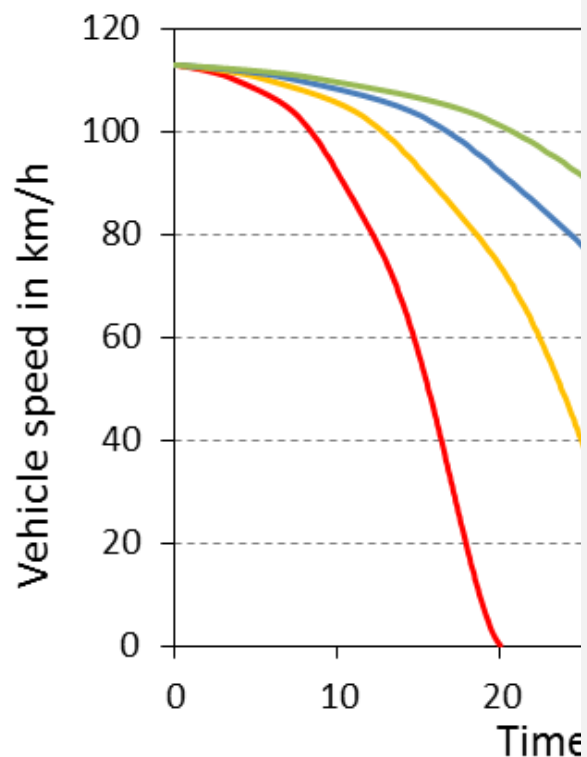


● 110 km/h case

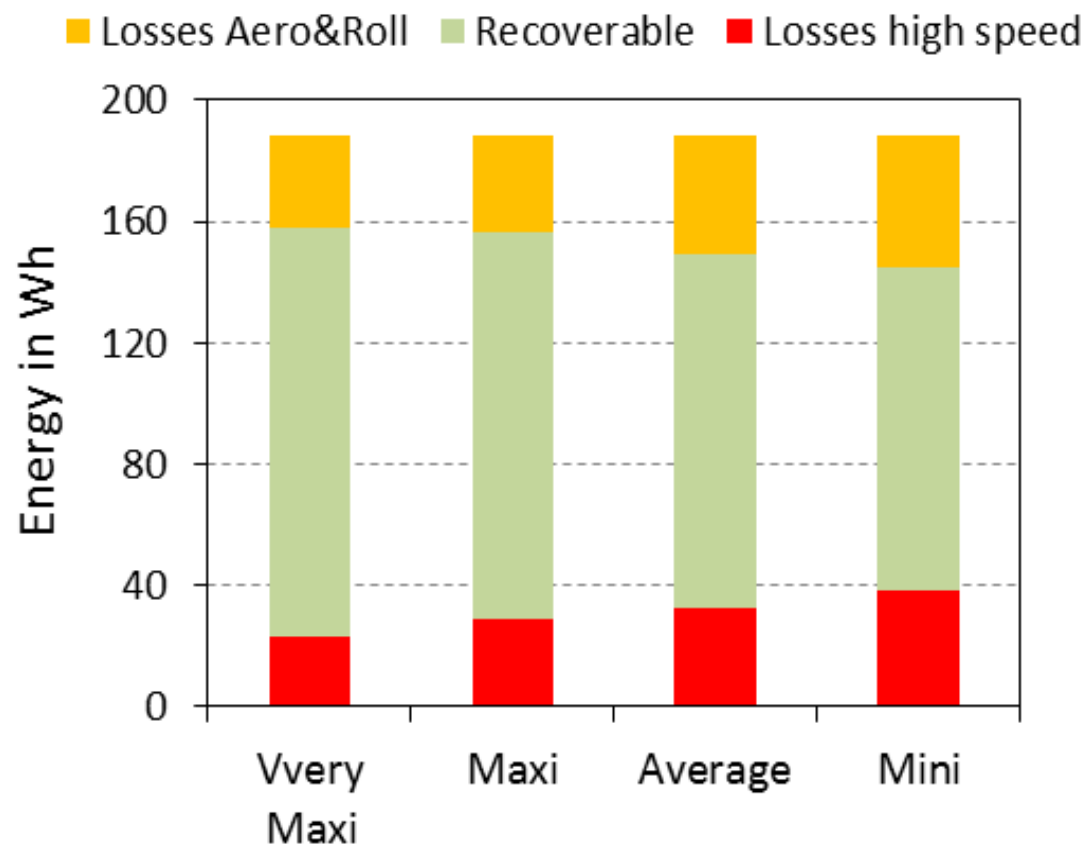


POWER AND ENERGY LOSSES IN DECELERATION (2/4)

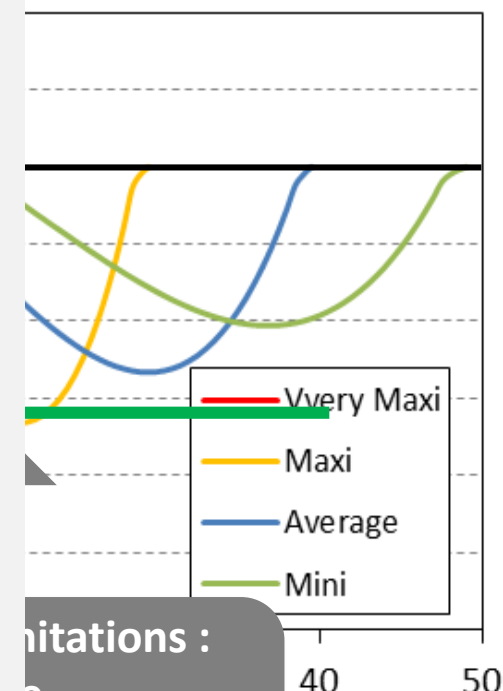
● 110 km/h case



Energy losses during decelerations



Aero & Roll Resist

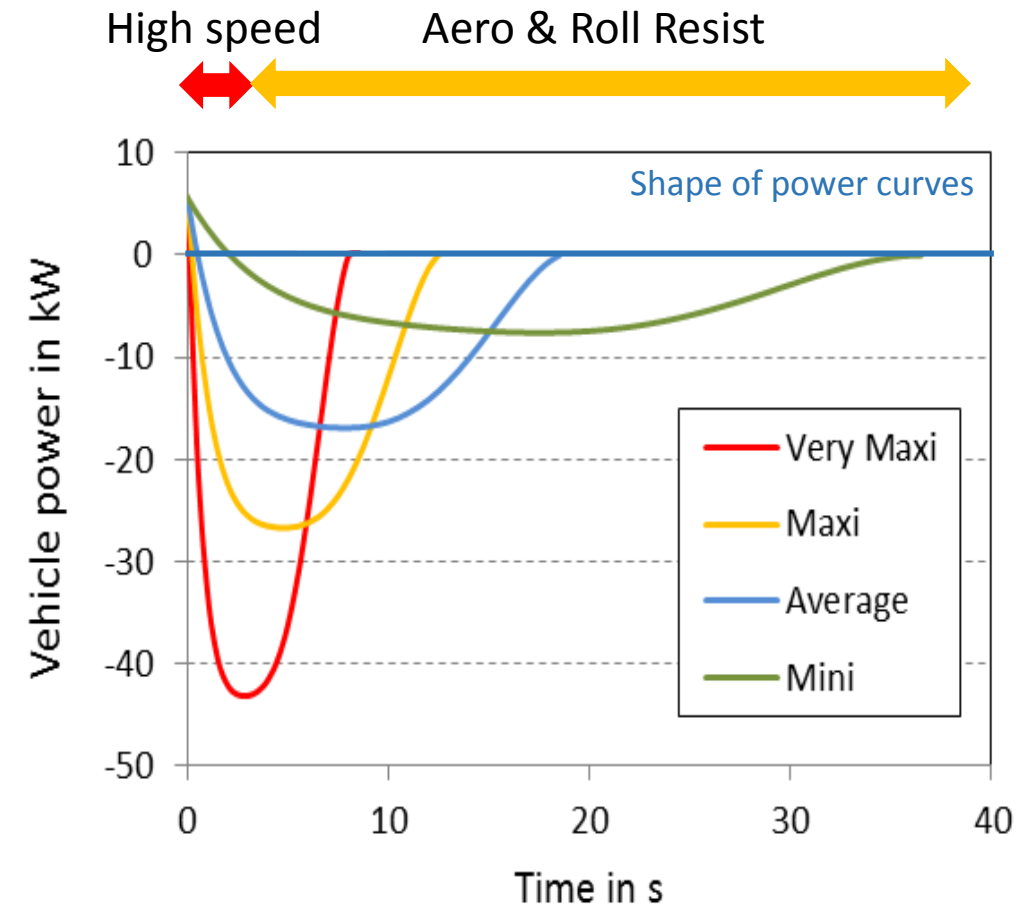
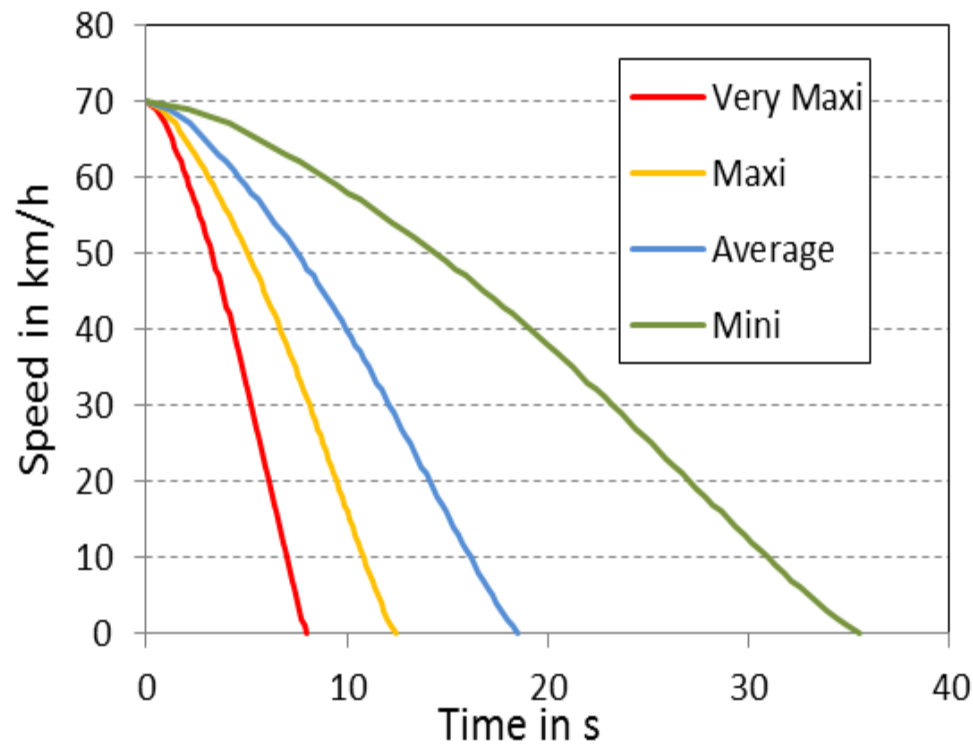


Limitations :

...e,
ent, voltage
efficient...

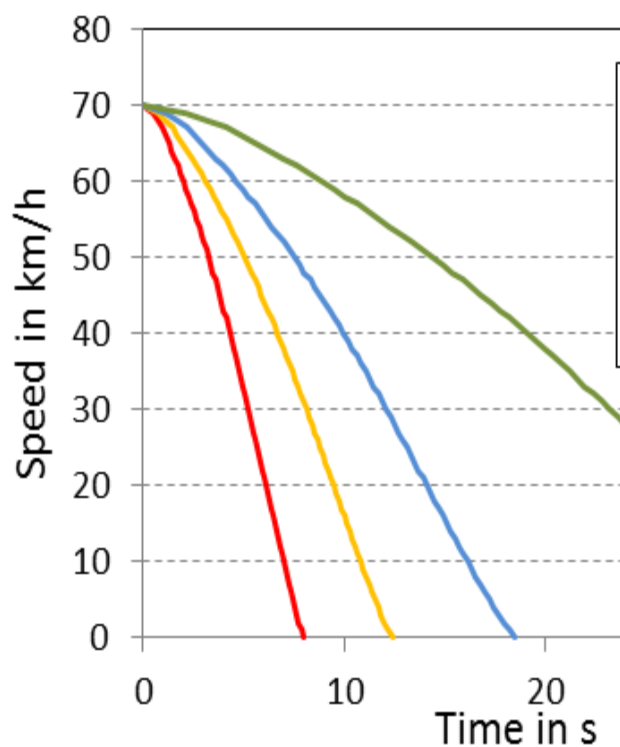
POWER AND ENERGY LOSSES IN DECELERATION (3/4)

70 km/h case

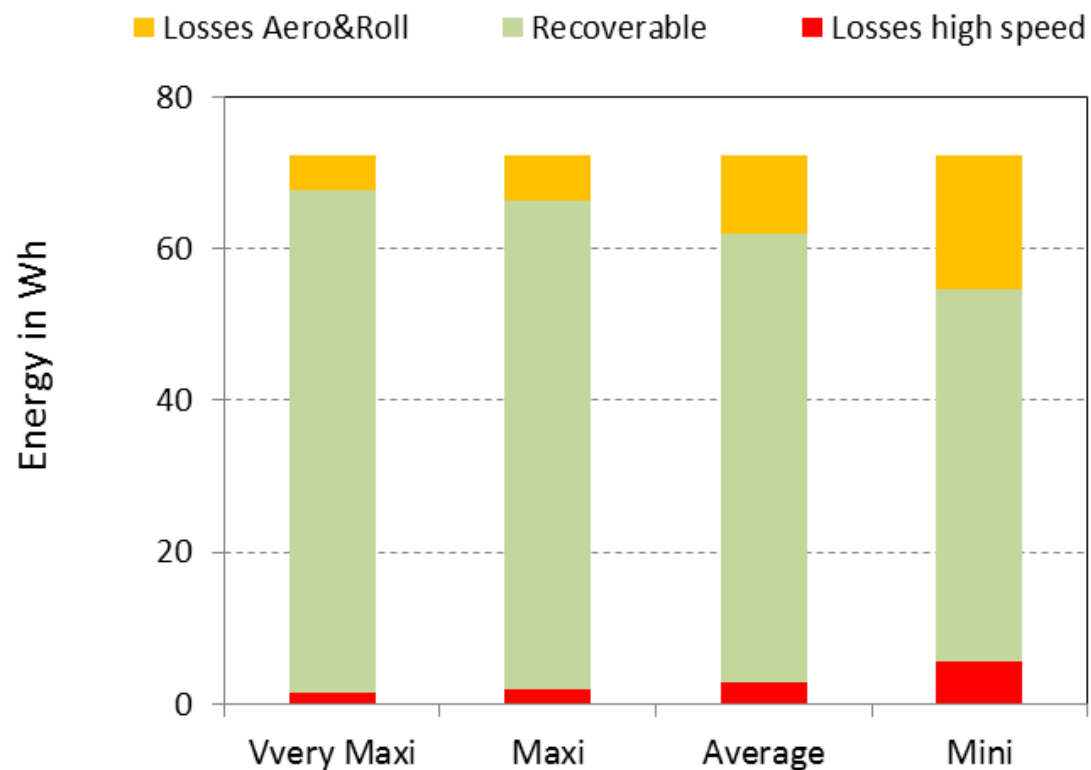


POWER AND ENERGY LOSSES IN DECELERATION (4/4)

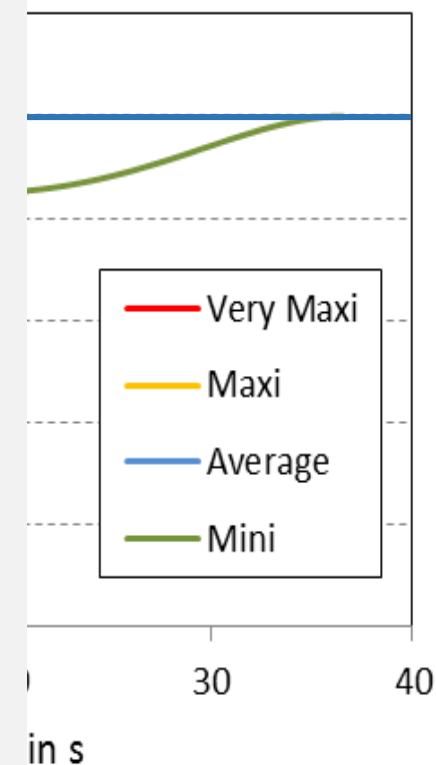
● 70 km/h case



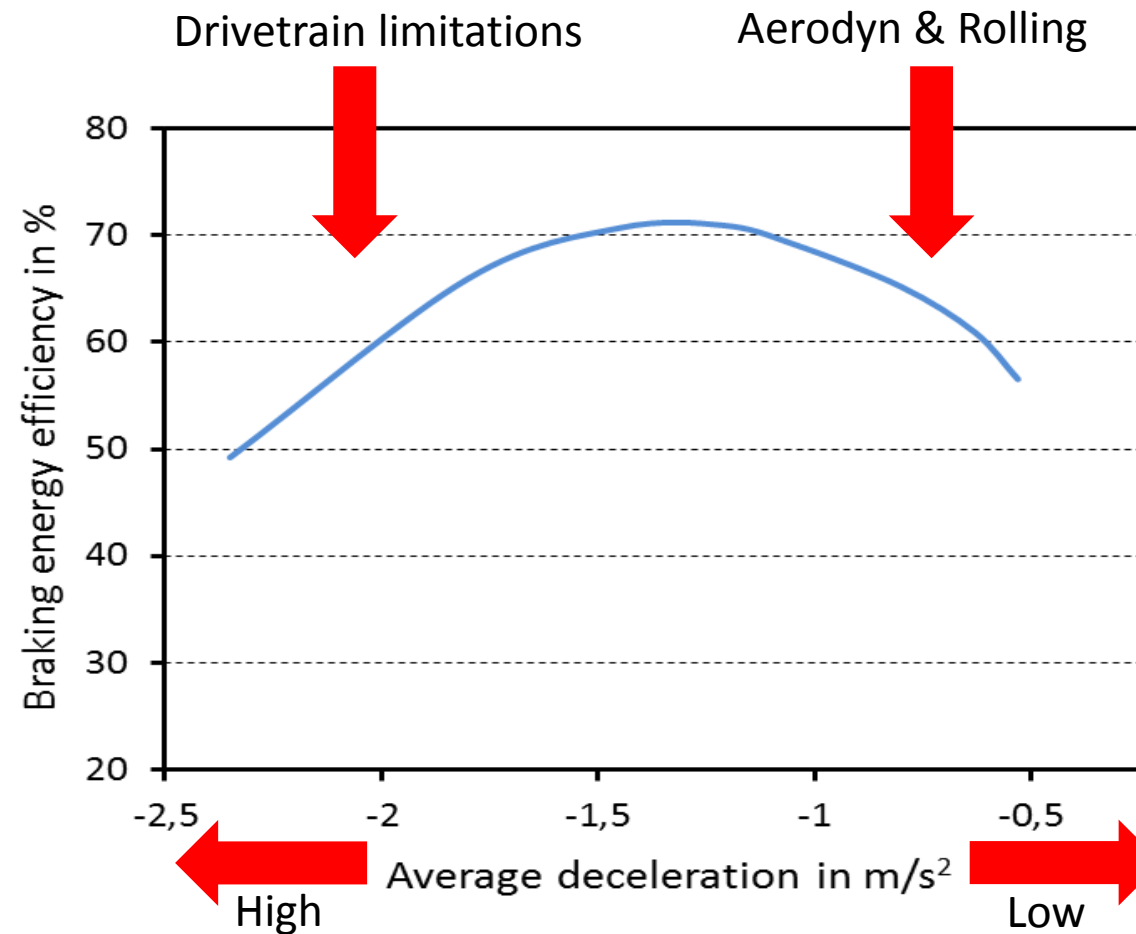
Energy losses during decelerations



assist



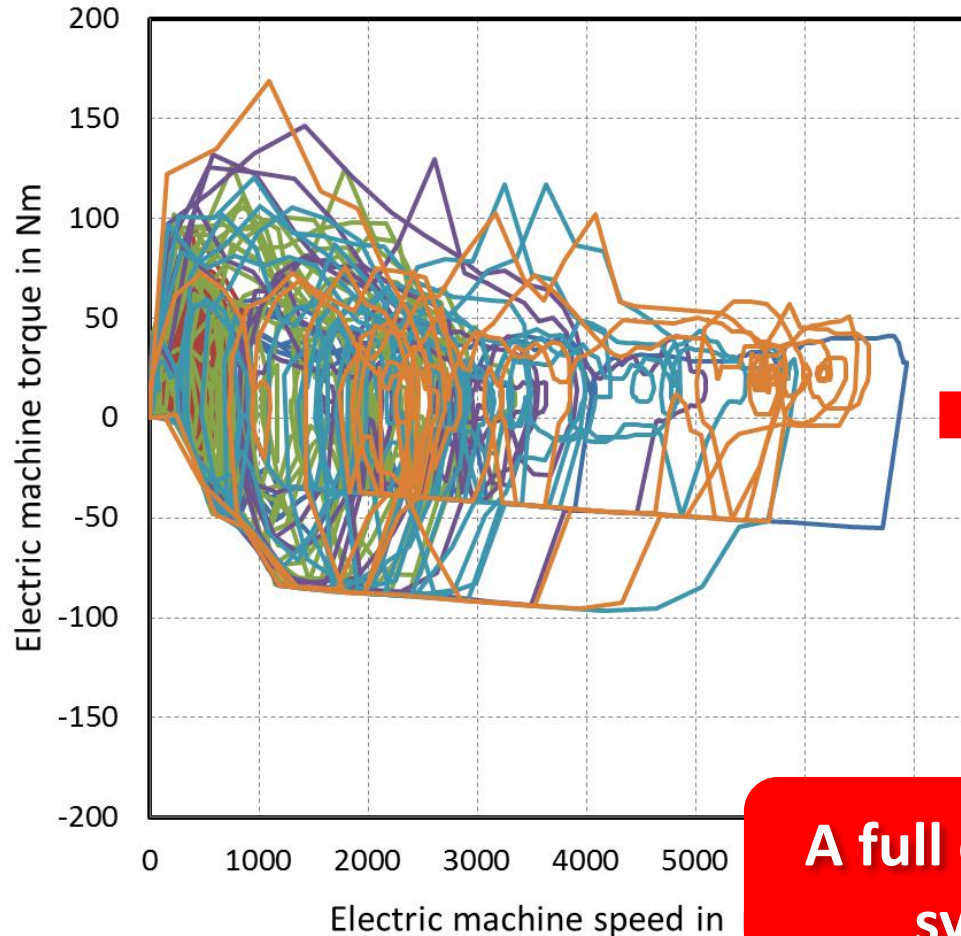
- Braking energy eff = (Energy at Wheel - Σ Components Losses) / Energy at Wheel



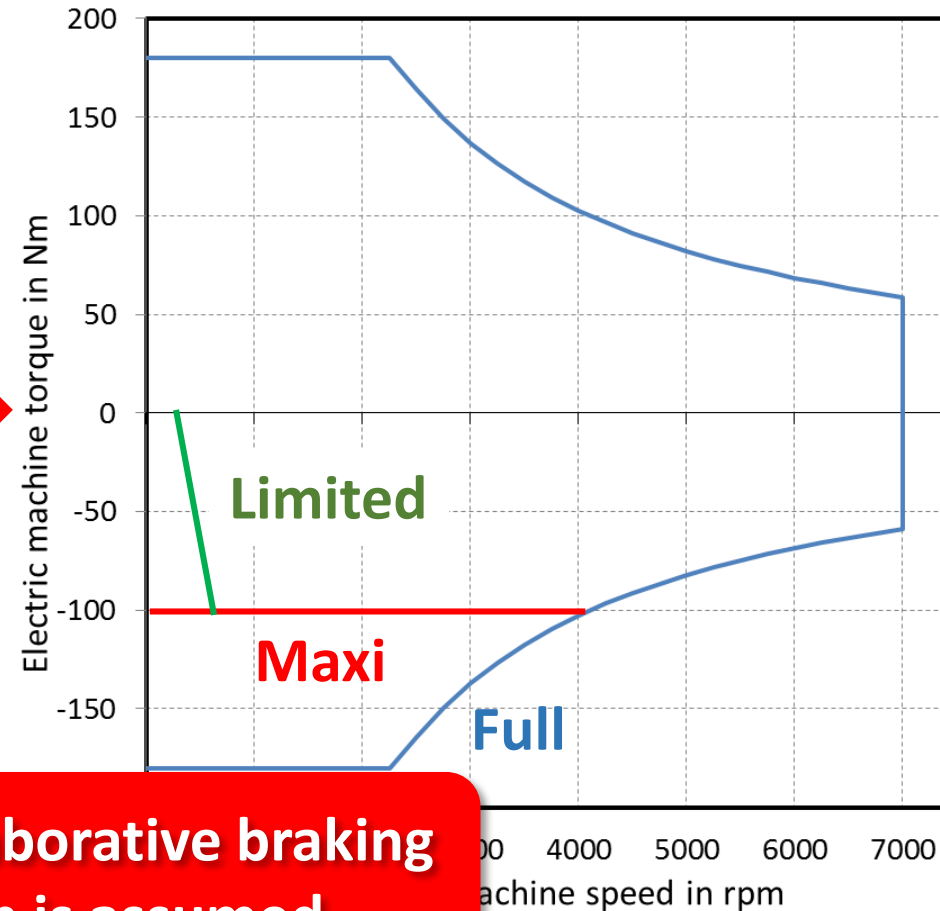
ELECTRIC DRIVETRAIN MAXIMUM CAPABILITIES

SUSTAINABLE MOBILITY

● EV actual use



● Limitations introduced in the software



Drivetrain
limitations
strategies

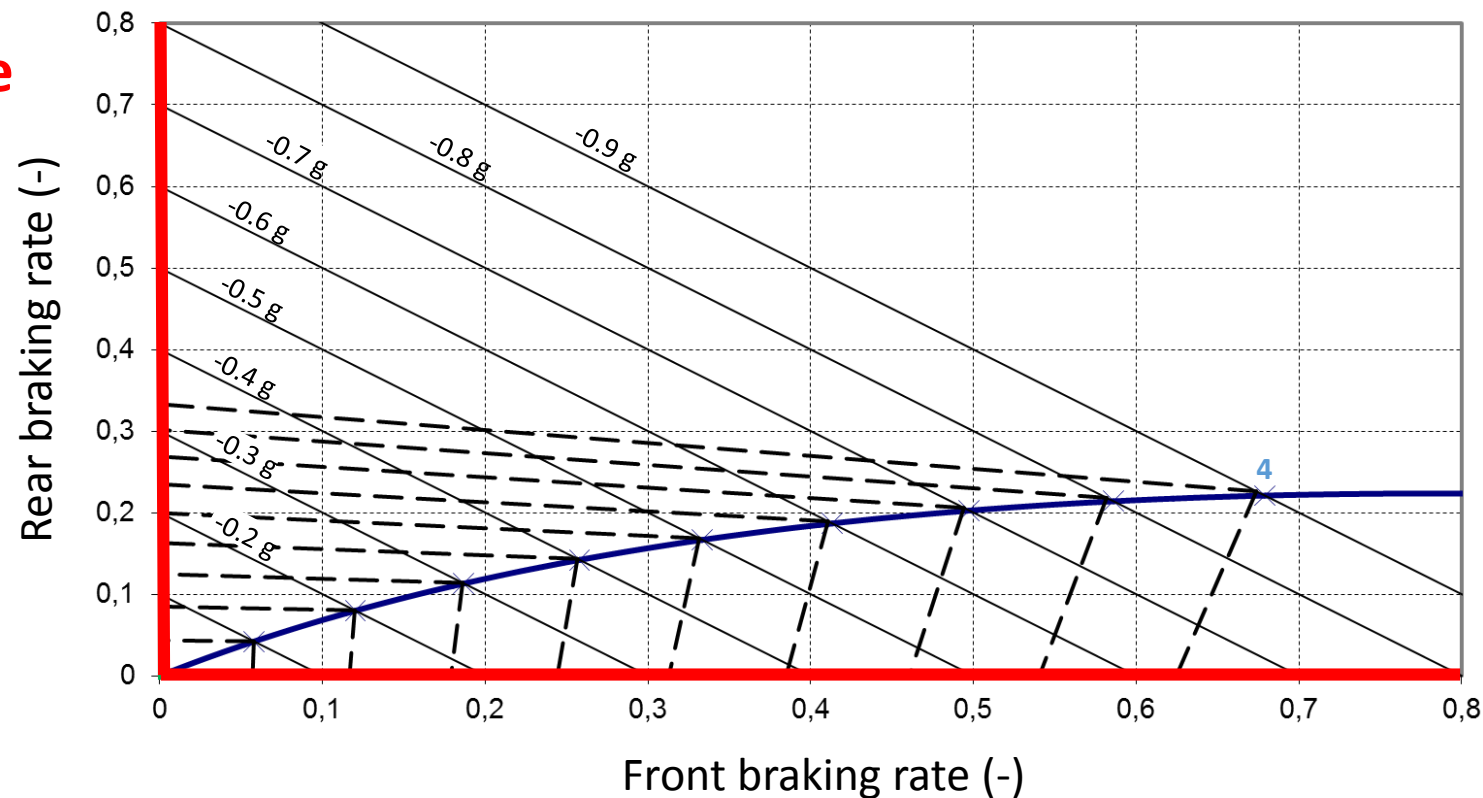
Limited
Maxi
Full

A full collaborative braking system is assumed

BRAKING ONLY ON THE MOTORING AXLE

- Maximize energy recovery
- Unrealistic theoretical case

Rear axle



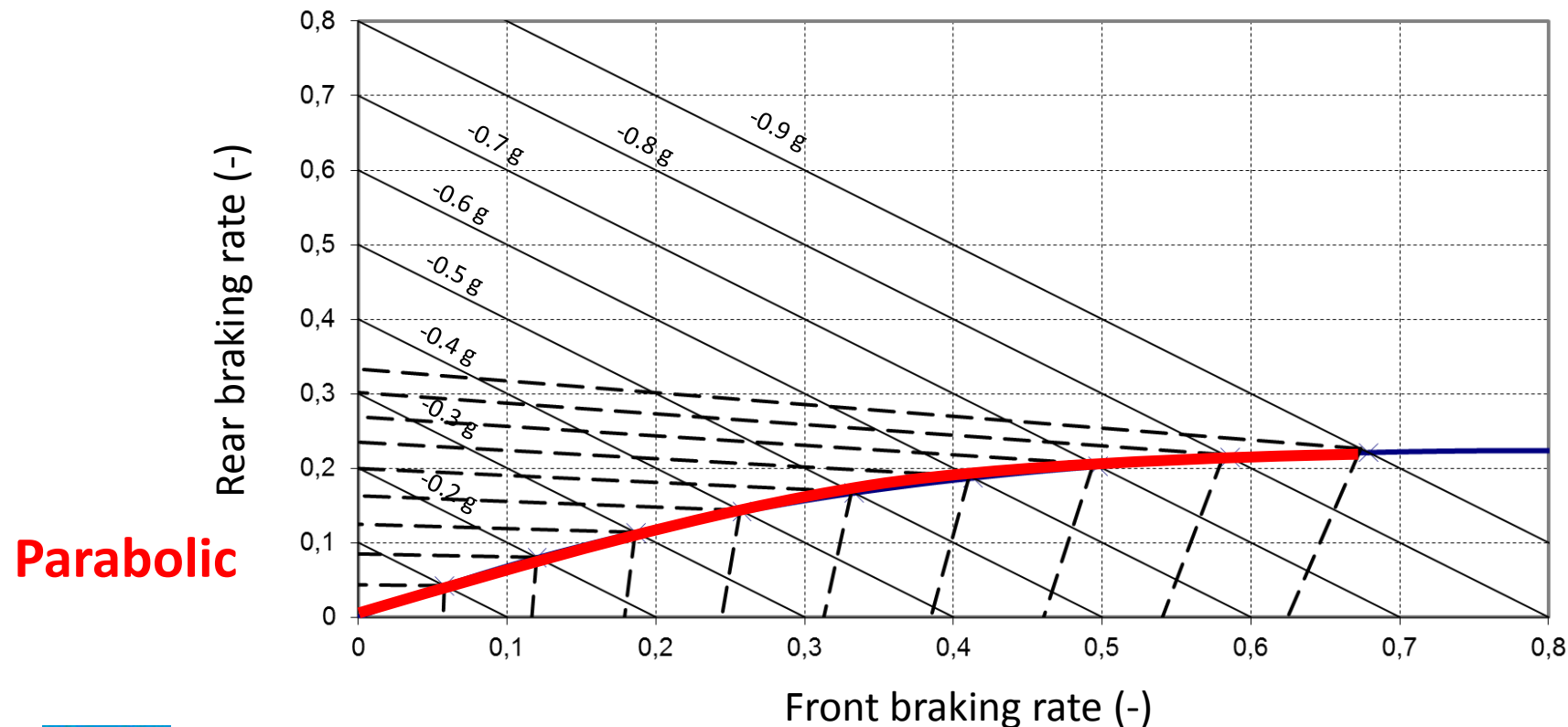
Braking
distribution
strategies

Front axle

BRAKING FORCE DISTRIBUTION ACCORDING TO THE EQUAL ADHESION PARABOLA

SUSTAINABLE MOBILITY

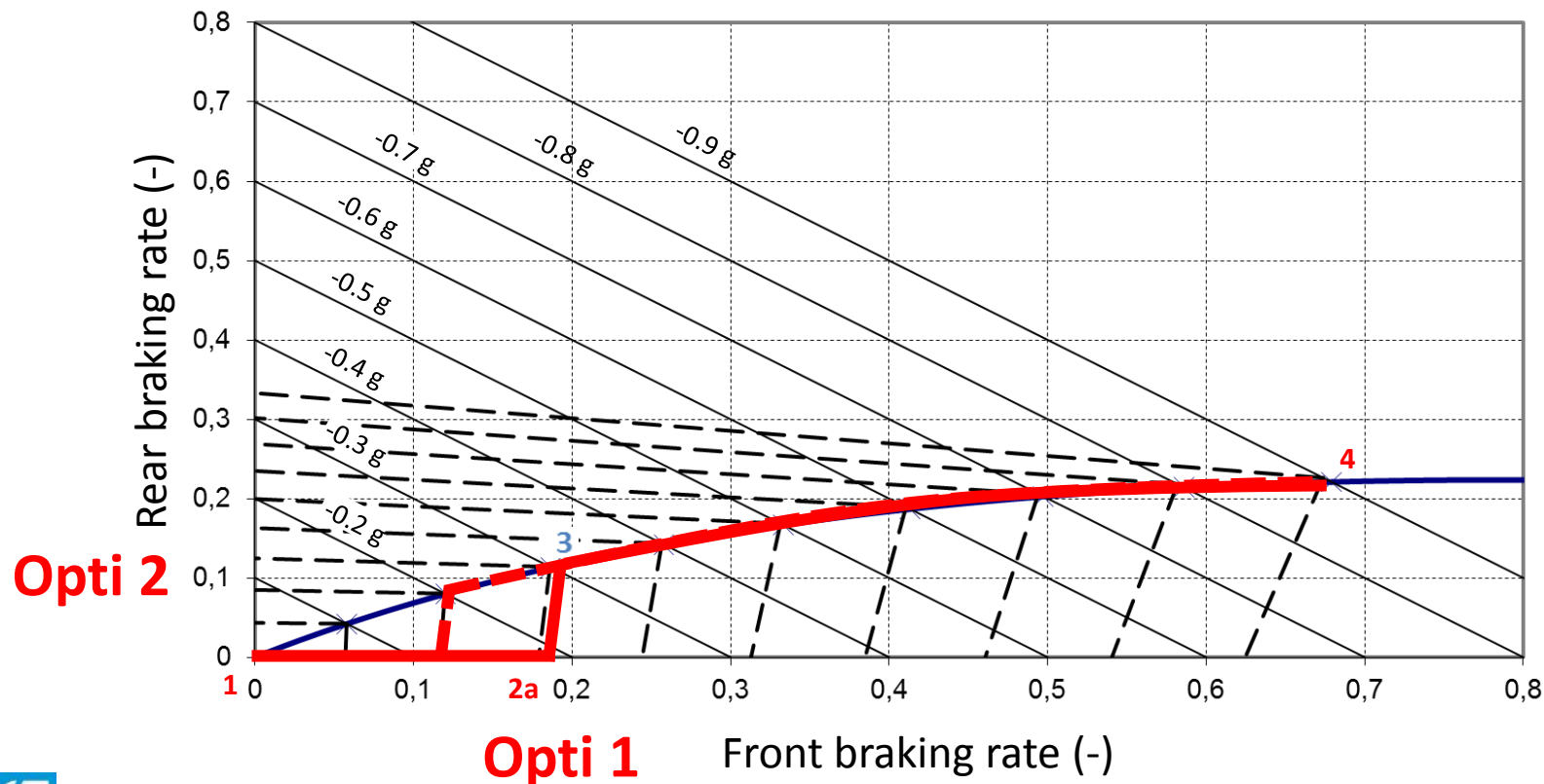
- Same μ on front and rear axis
- Recovery energy sharing between axles in all situations



BRAKING FORCE DISTRIBUTION FAVORING MOTORING AXLE THEN EQUAL ADHESION PARABOLA (**FRONT**)

SUSTAINABLE MOBILITY

- Motoring axle only for low μ (front)
- Distribution according to equal adhesion parabola for higher rates

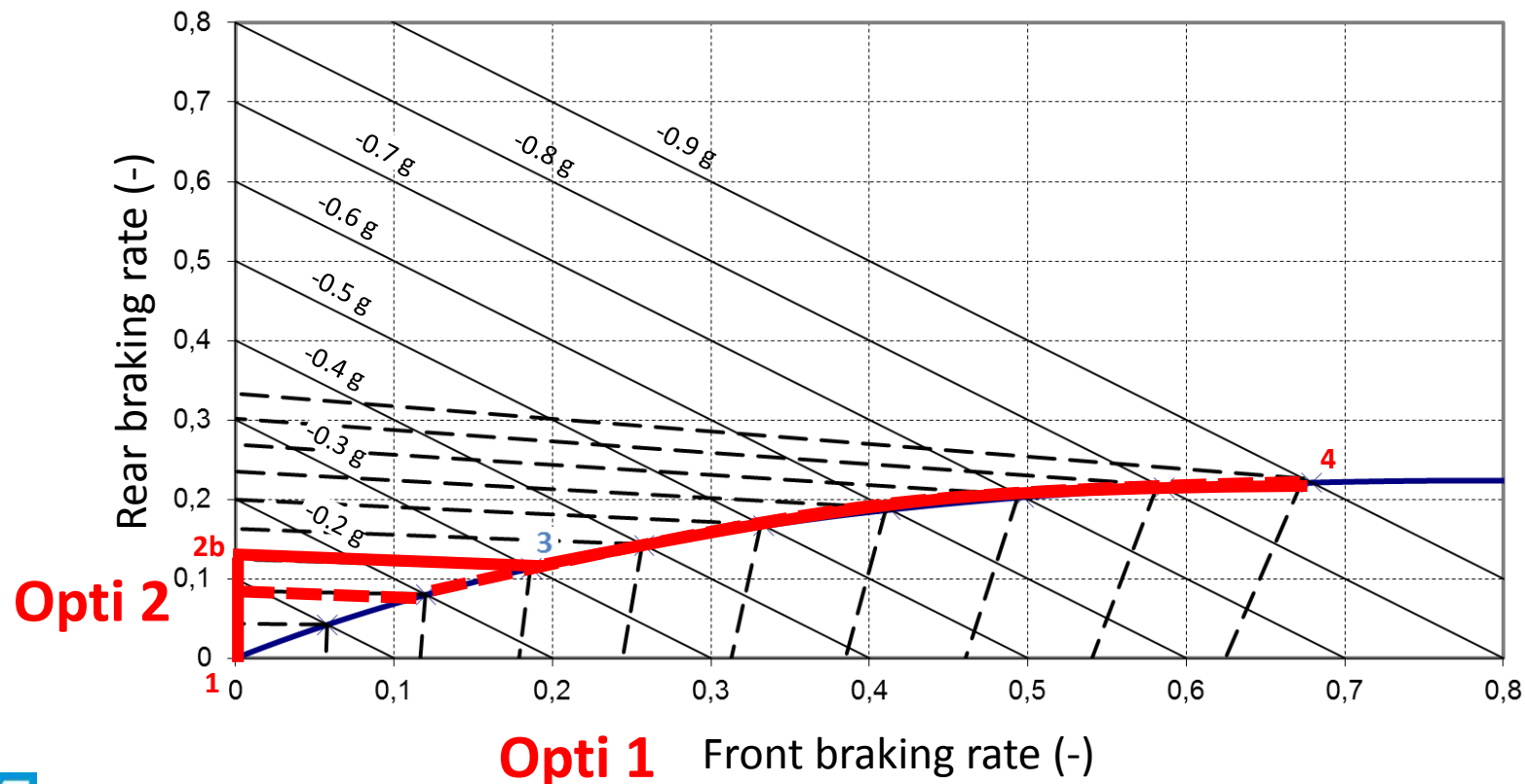


Braking
distribution
strategies

- 2 threshold values :
- 0.3 m/s^2 : Opti 1
 - 0.2 m/s^2 : Opti 2

BRAKING FORCE DISTRIBUTION FAVORING MOTORING AXLE THEN EQUAL ADHESION PARABOLA (REAR)

- Motoring axle only for low μ (rear)
- Distribution according to equal adhesion parabola for higher rates



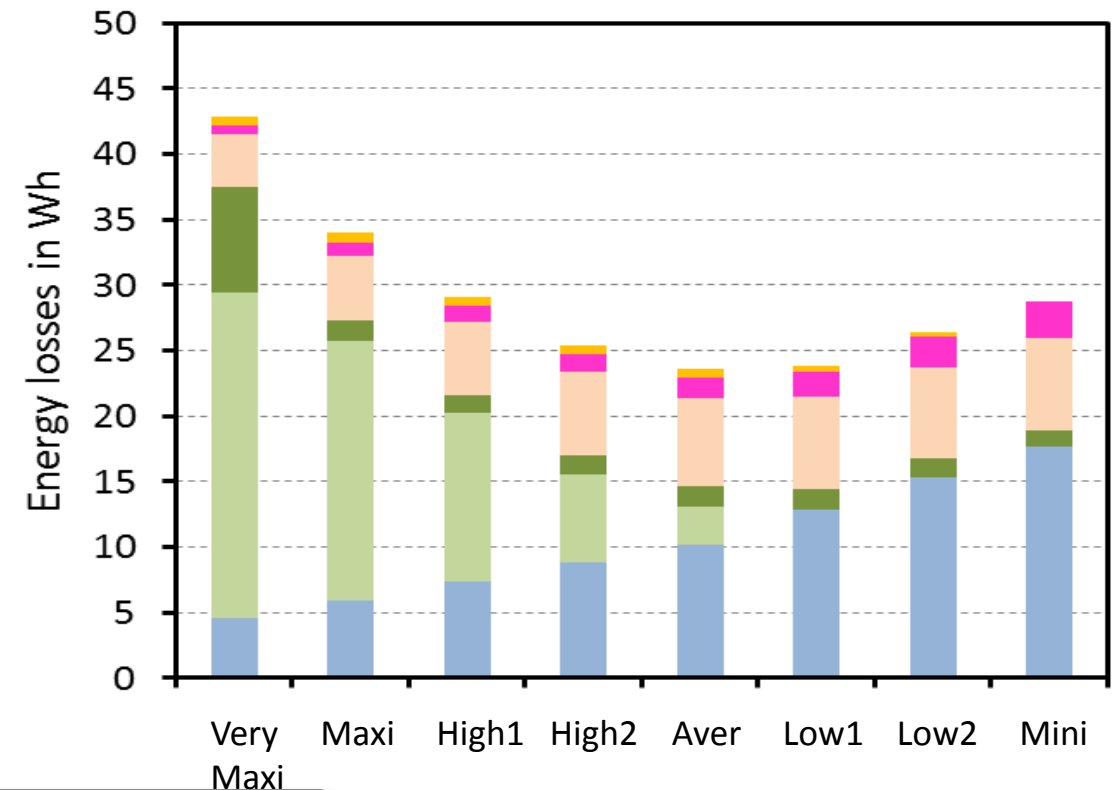
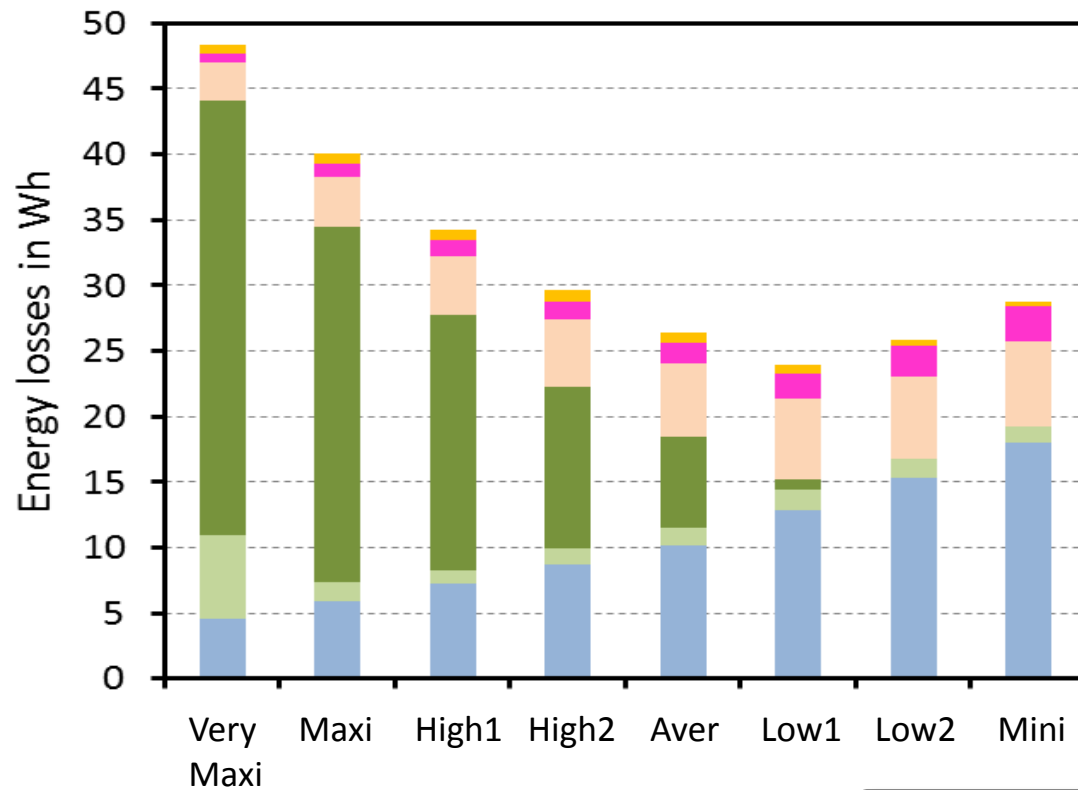
ENERGY LOSSES DISTRIBUTION IN THE COMPONENTS DURING BRAKING PHASES

SUSTAINABLE MOBILITY

Rear
motoring axle



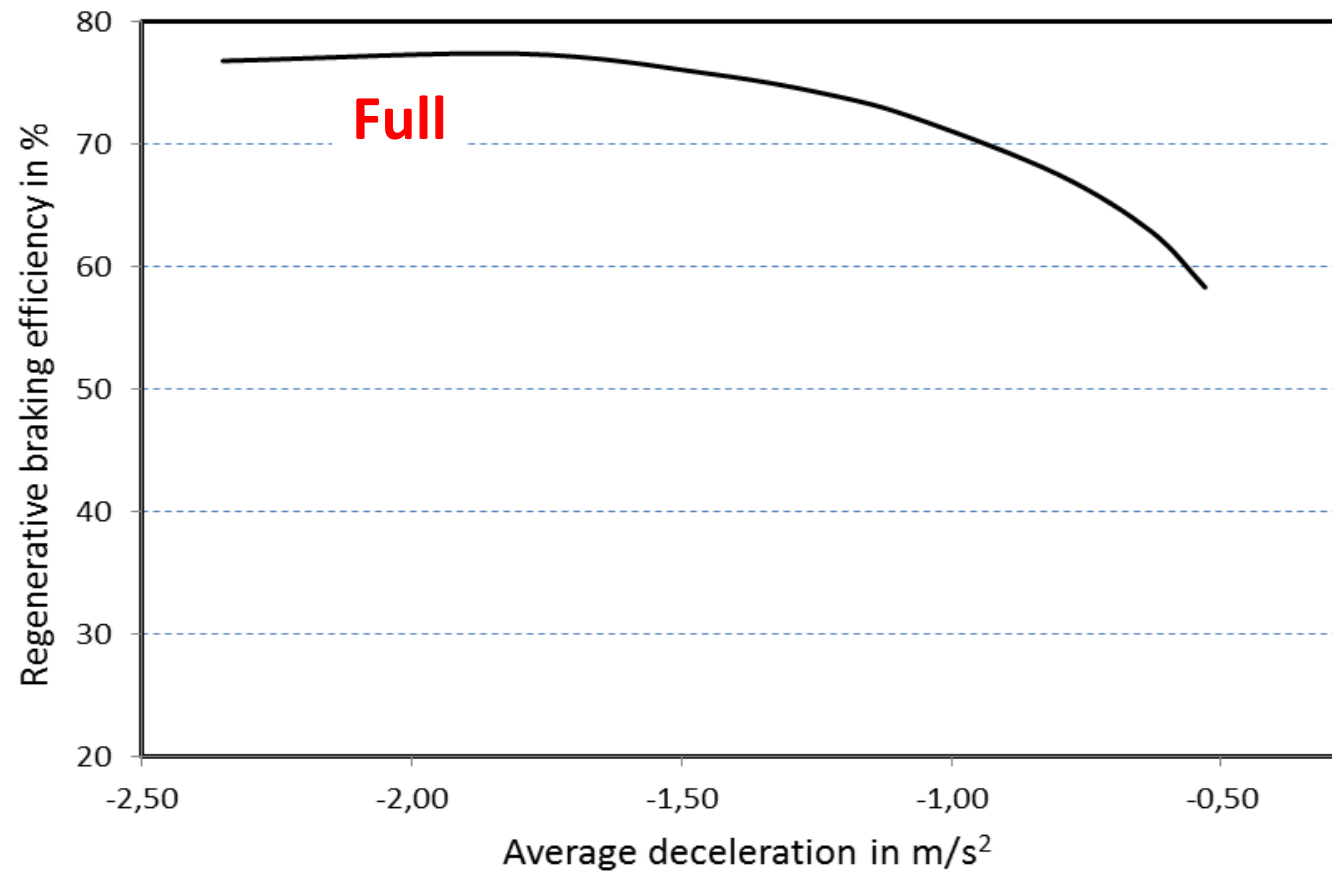
Front
motoring axle



Energy losses only represented

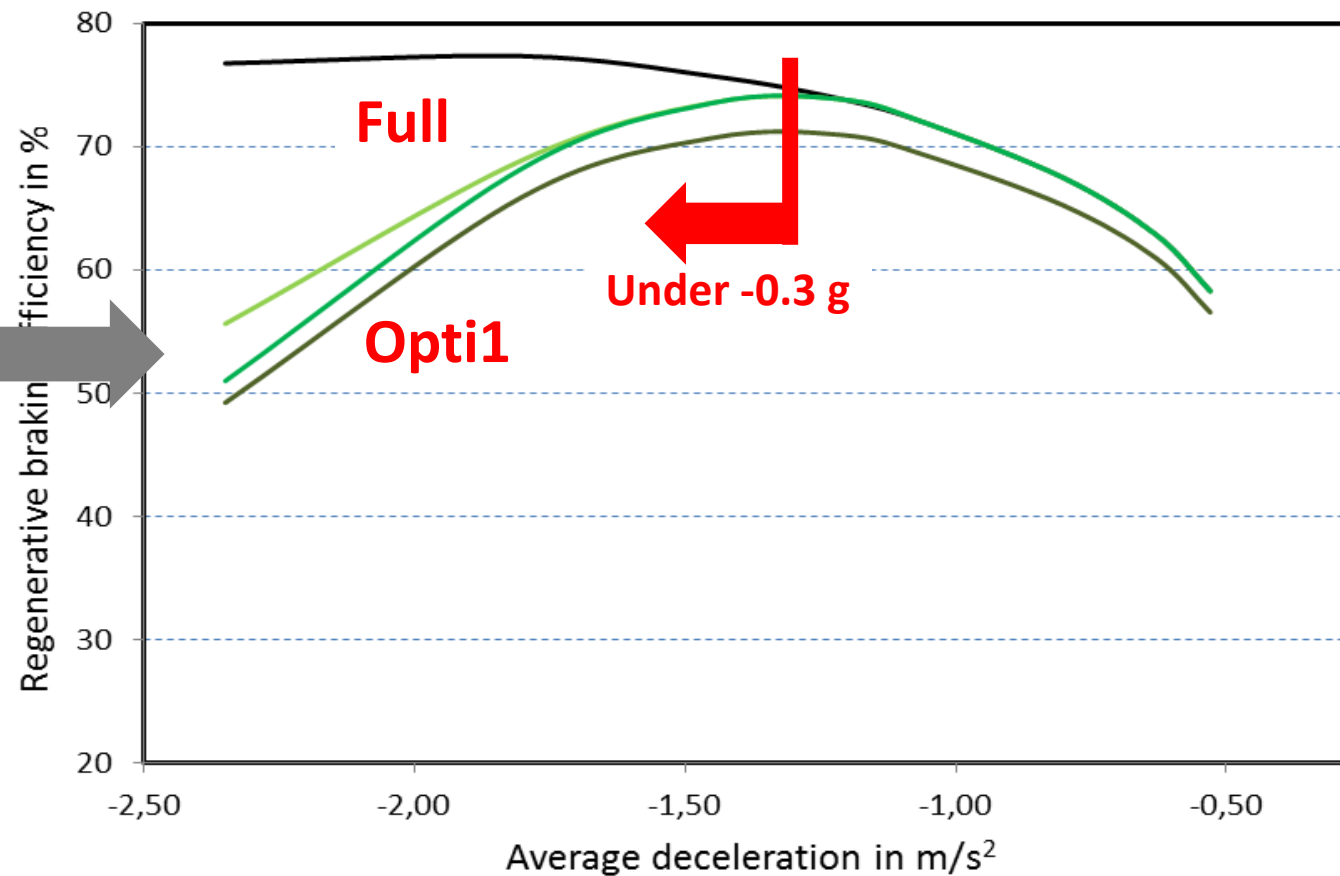
EVOLUTION OF REGENERATIVE ENERGY EFFICIENCY (1/4)

- Full regen (theoretical hypothesis)



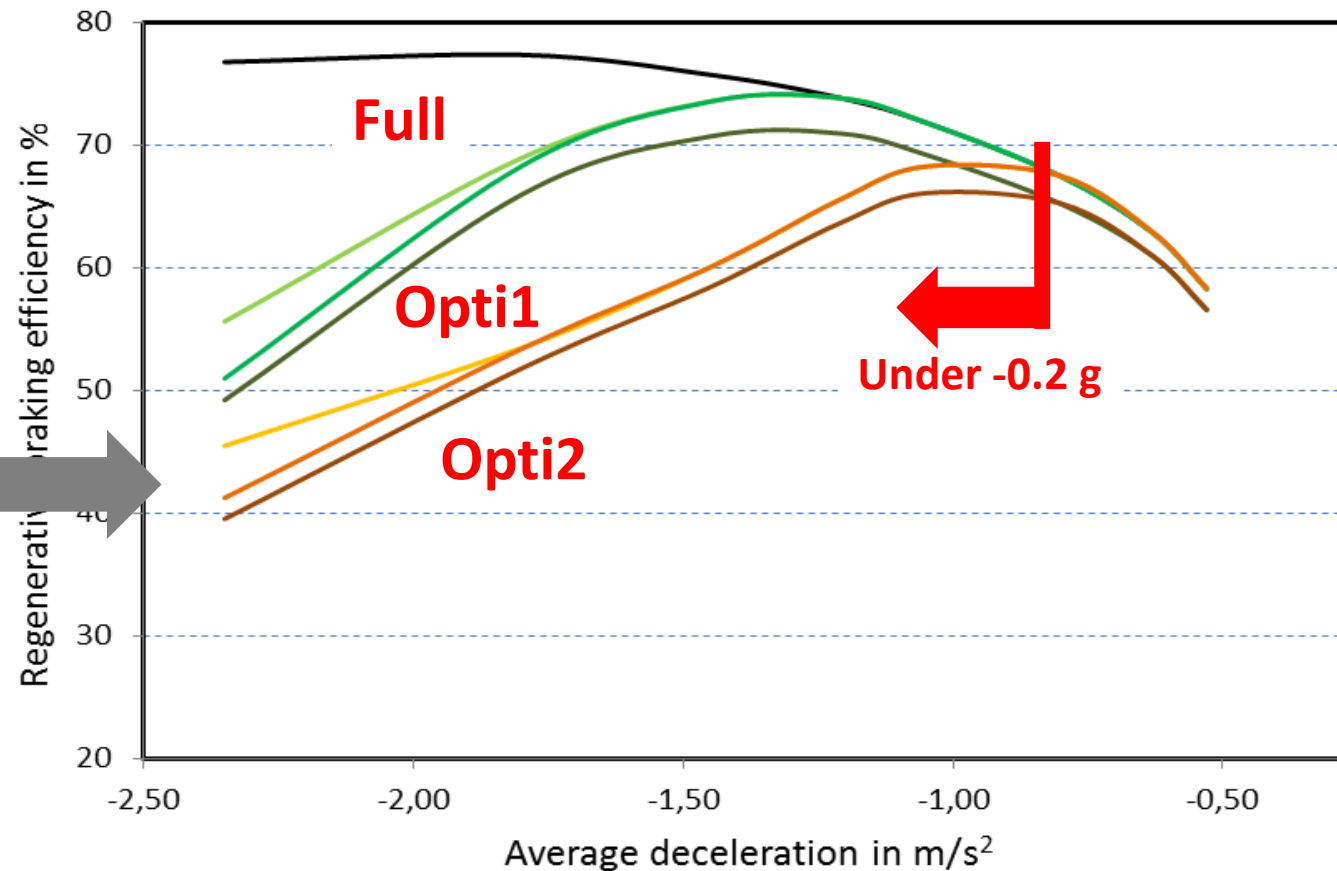
EVOLUTION OF REGENERATIVE ENERGY EFFICIENCY (2/4)

- Opti1 : Motoring axle only up to 0.3 g then parabola



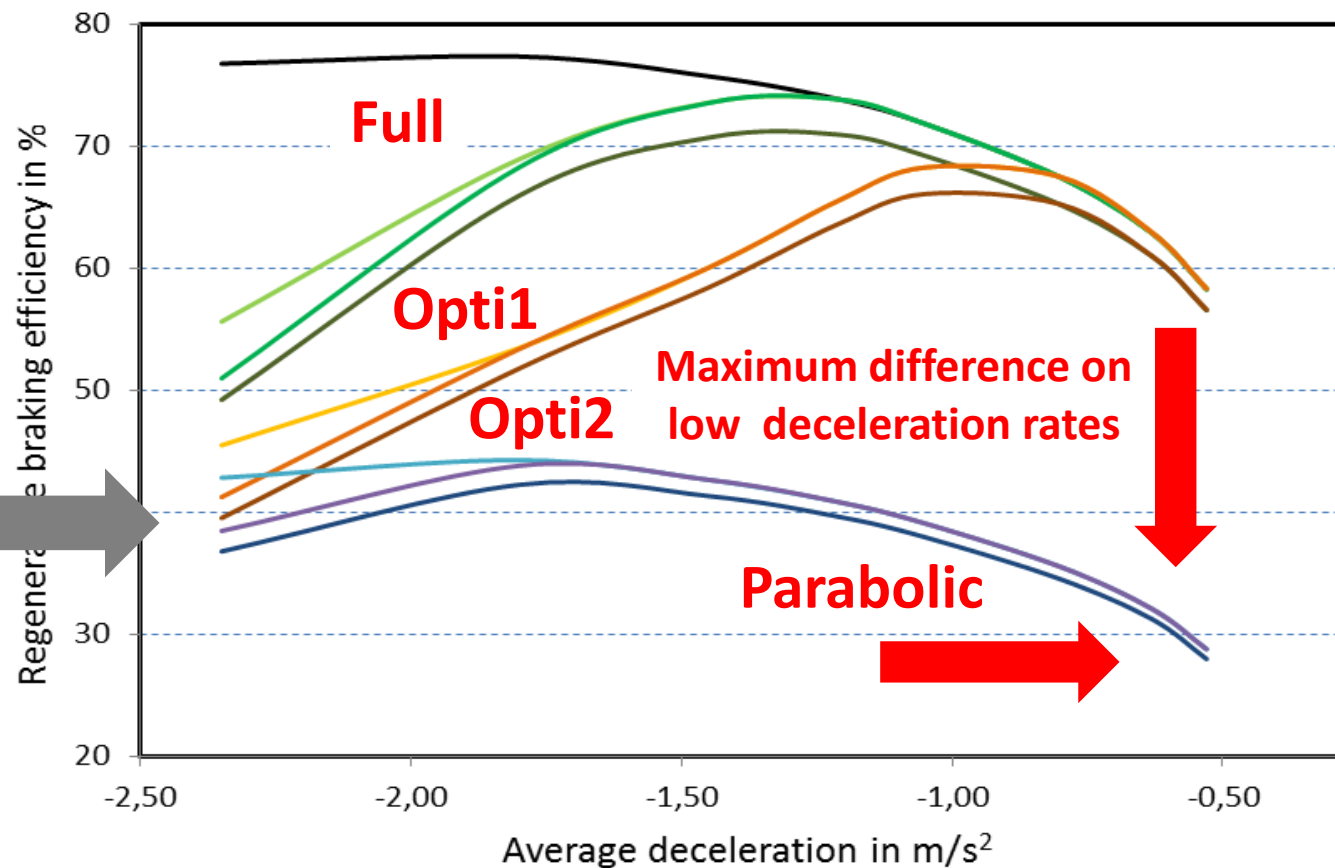
EVOLUTION OF REGENERATIVE ENERGY EFFICIENCY (3/4)

- Opti2 : Motoring axle only up to 0.2 g then parabola



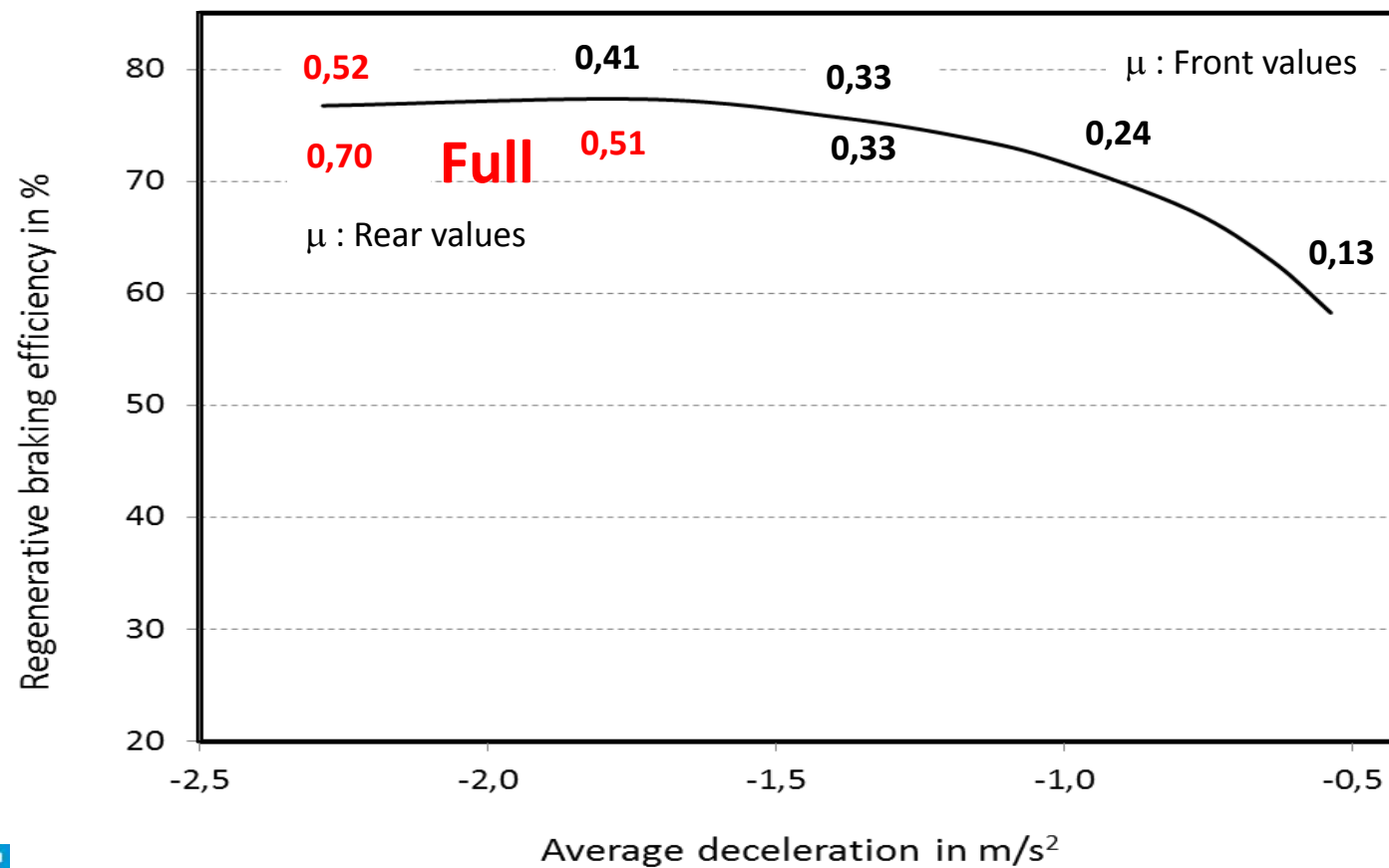
EVOLUTION OF REGENERATIVE ENERGY EFFICIENCY (4/4)

- Recovery energy sharing between axles in all situations



EFFICIENCY COMPARISON FOR FRONT AND REAR DRIVETRAINS (1/3)

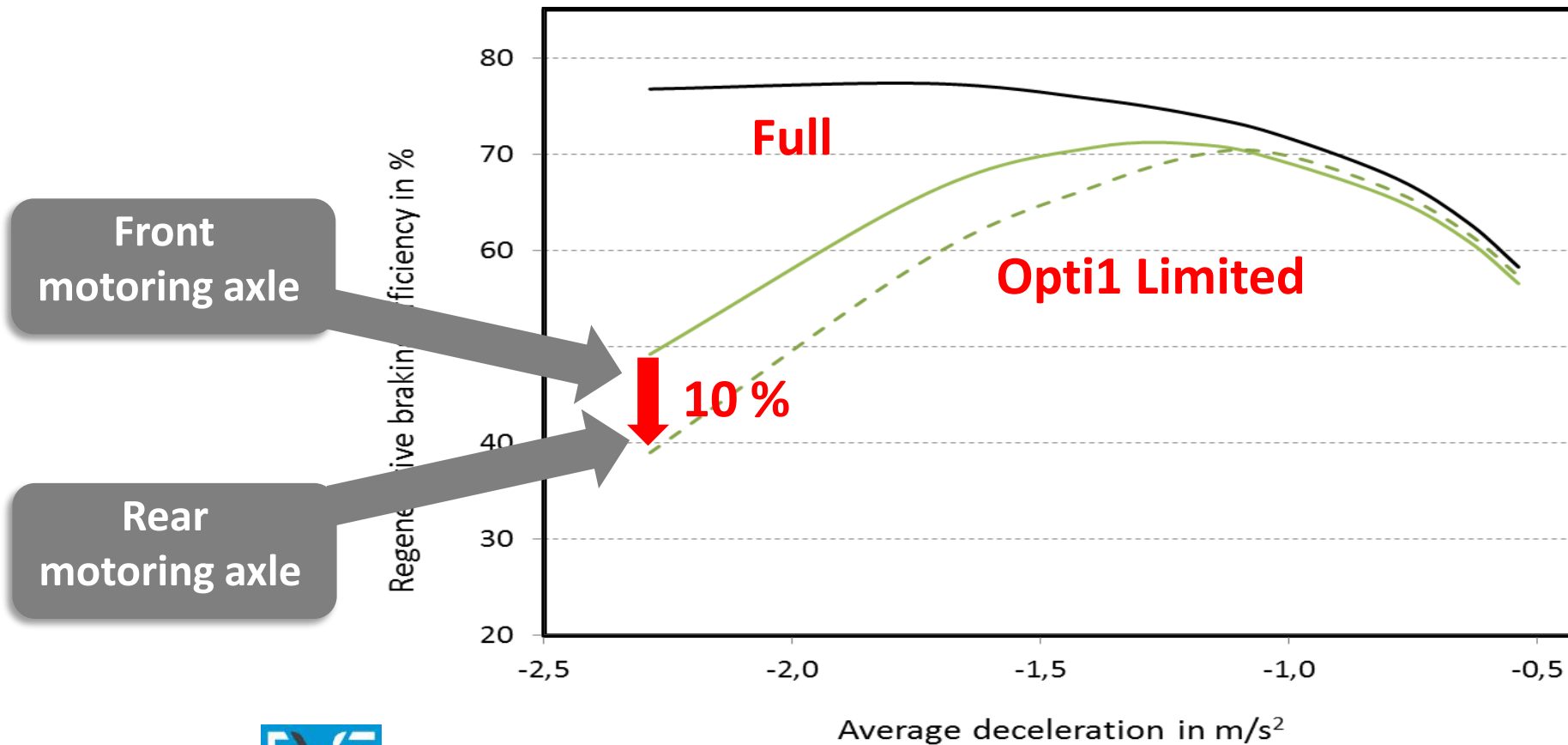
- Motoring axle only, front and rear



Braking
distribution
strategies

EFFICIENCY COMPARISON FOR FRONT AND REAR DRIVETRAINS (2/3)

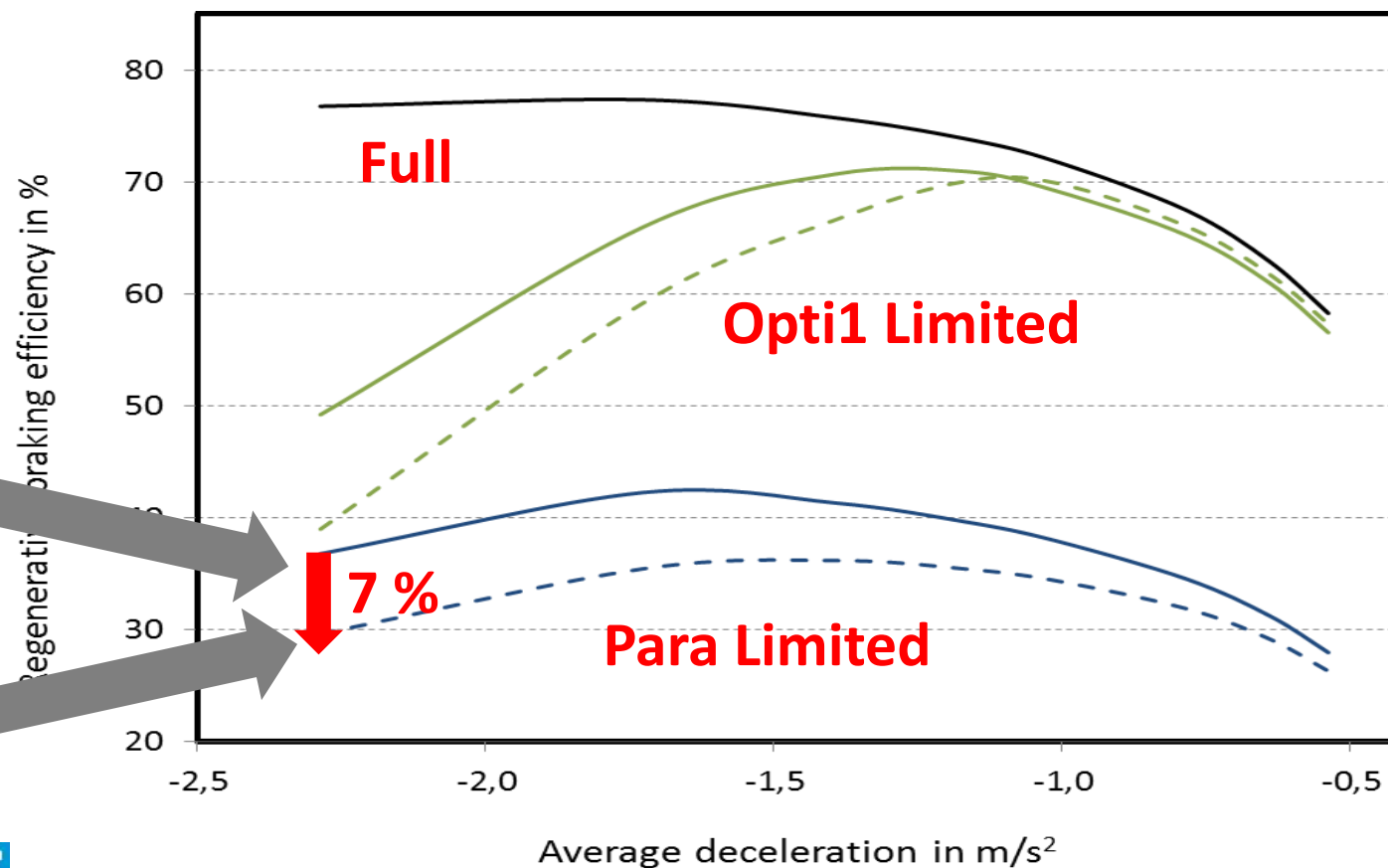
- Plus : Opti1 Limited strategy, front and rear



Braking
distribution
strategies

EFFICIENCY COMPARISON FOR FRONT AND REAR DRIVETRAINS (3/3)

- Plus : Para Limited strategy, front and rear



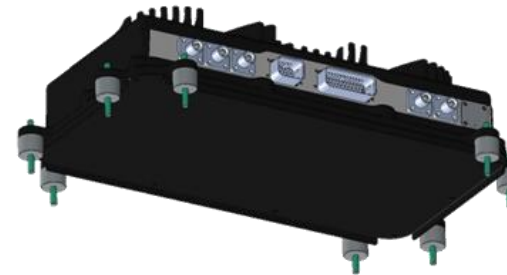
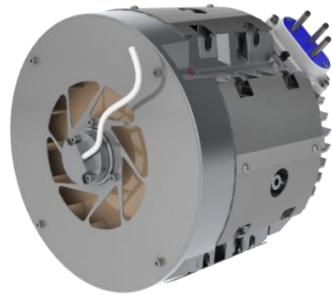
Front
motoring axle

Rear
motoring axle

Braking
distribution
strategies

- **Validated software** is of high interest to evaluate energy behavior of electrified vehicles drivetrains ;
- **Great potential** in energy recovery during braking (45 % to 65% of the wheel energy) in urban/suburban uses ;
- Maximum energy efficiency reached for **intermediate decelerations** => **Automated vehicles** ;
- Collaborative strategy favoring the **motoring axle on low decelerations** appears to be the most efficient (influence of the threshold value 10 to 15 %) ;
- **Limitations on drivetrain** maximum capabilities will **reduce the energy recovery efficiency** for the toughest deceleration cases ;
- Phasing out braking torque at low speed for comfort will have a limited influence (3 to 6%) ;
- Strategies to **be implemented in our drivetrain products**

IFPEN is developing a range of high efficient and optimized cost motors and inverters for e-mobility...



... From prototyping to production
(high volume capabilities)

In collaboration with



Visit or Booth in AVERE France (stand 1709)

Innovating for energy



Find us on:

 www.ifpenergiesnouvelles.com

 @IFPENinnovation

