The Hydrid

a series hydraulic hybrid transmission

Peter Achten

I N N A S

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Las Vegas, March 12-14, 2008

Vision BMW

Carsten Breitfeld

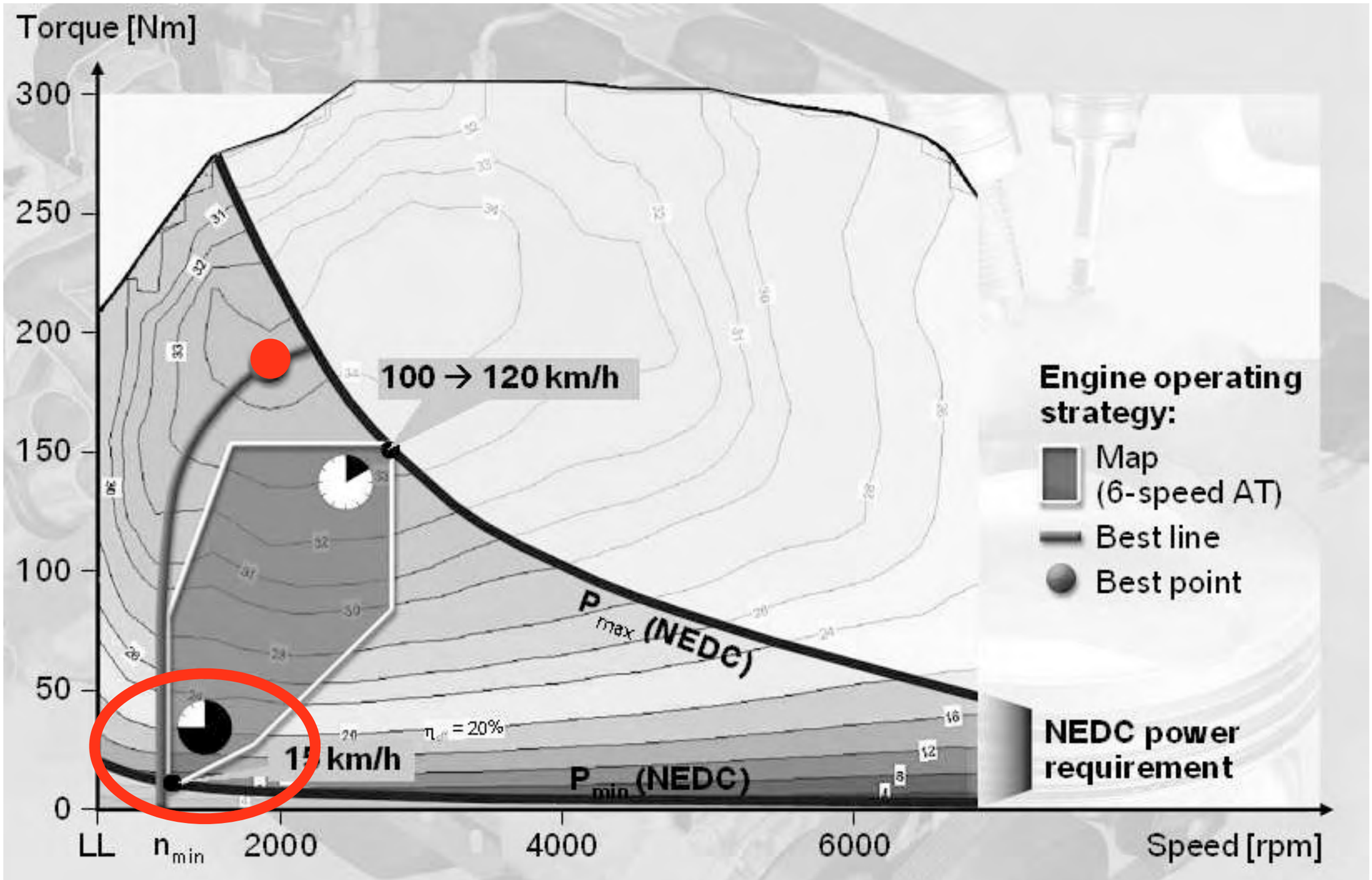
Vice-President
transmission and drive train development

Vision BMW

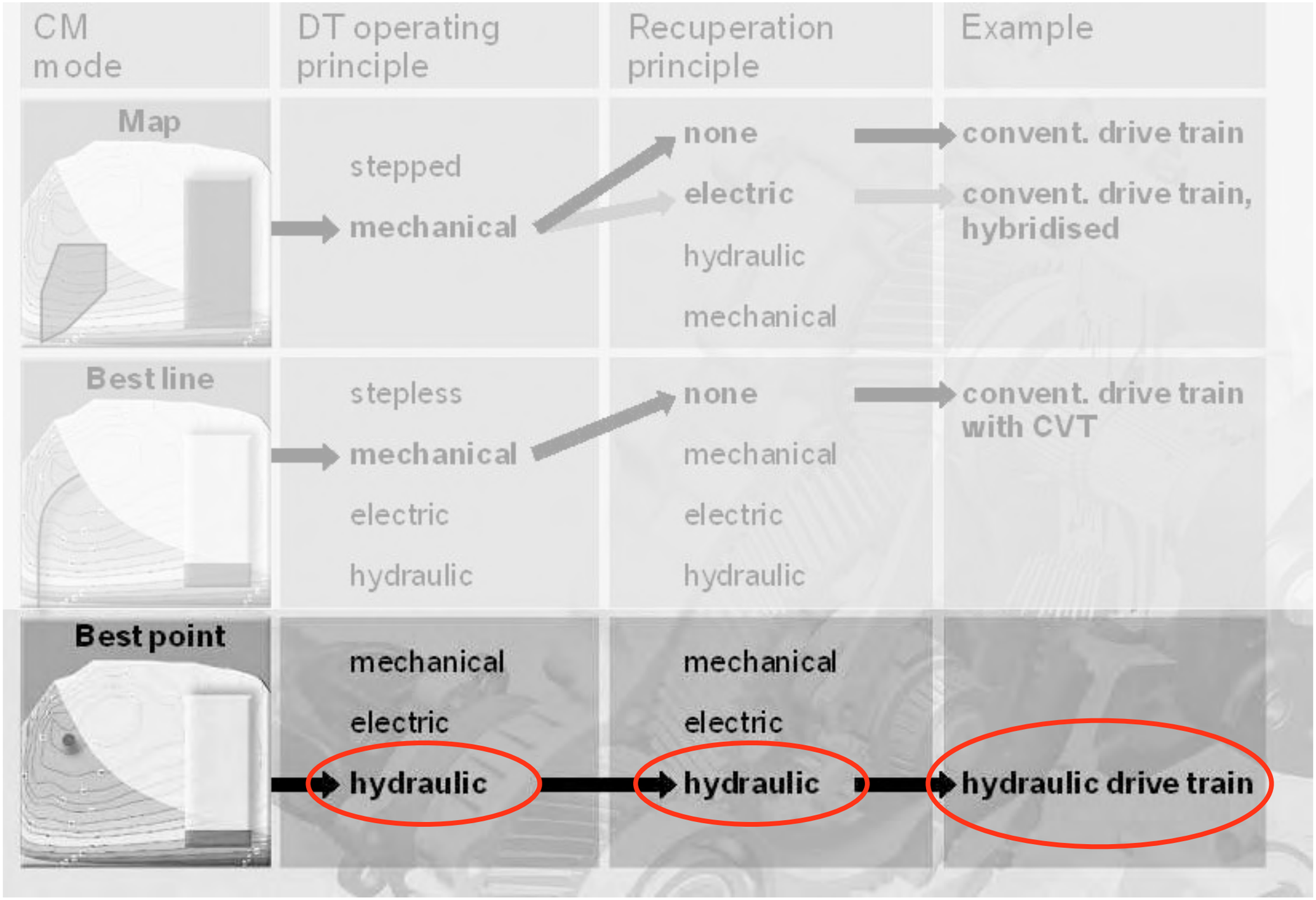
Carsten Breitfeld

6th international CTI symposium
‘Innovative Automotive Transmissions’
3 - 7 December 2007

Vision BMW


Torque [Nm]
300
250
200
150
100
50
0
LL
n_{min}
2000
4000
6000
Speed [rpm]
100 → 120 km/h
15 km/h
P_{max} (NEDC)
P_{min} (NEDC)
η_{el} = 20%
Engine operating strategy:
Map (6-speed AT)
Best line
Best point
NEDC power requirement

Vision BMW


CM mode
DT operating principle
Recuperation principle
Example
Map
stepped
mechanical
none
electric
hydraulic
mechanical
convent. drive train
convent. drive train, hybridised
Best line
stepless
mechanical
electric
hydraulic
none
mechanical
electric
hydraulic
convent. drive train with CVT
Best point
mechanical
electric
hydraulic
mechanical
electric
hydraulic
hydraulic drive train

Vision BMW

- extensive modification of the drive-train needed
- engine speed and torque must be decoupled
- energy storage is needed
- gasoline engine:
  3,3 litre per100 km (NEDC)

things you shouldn’t do:

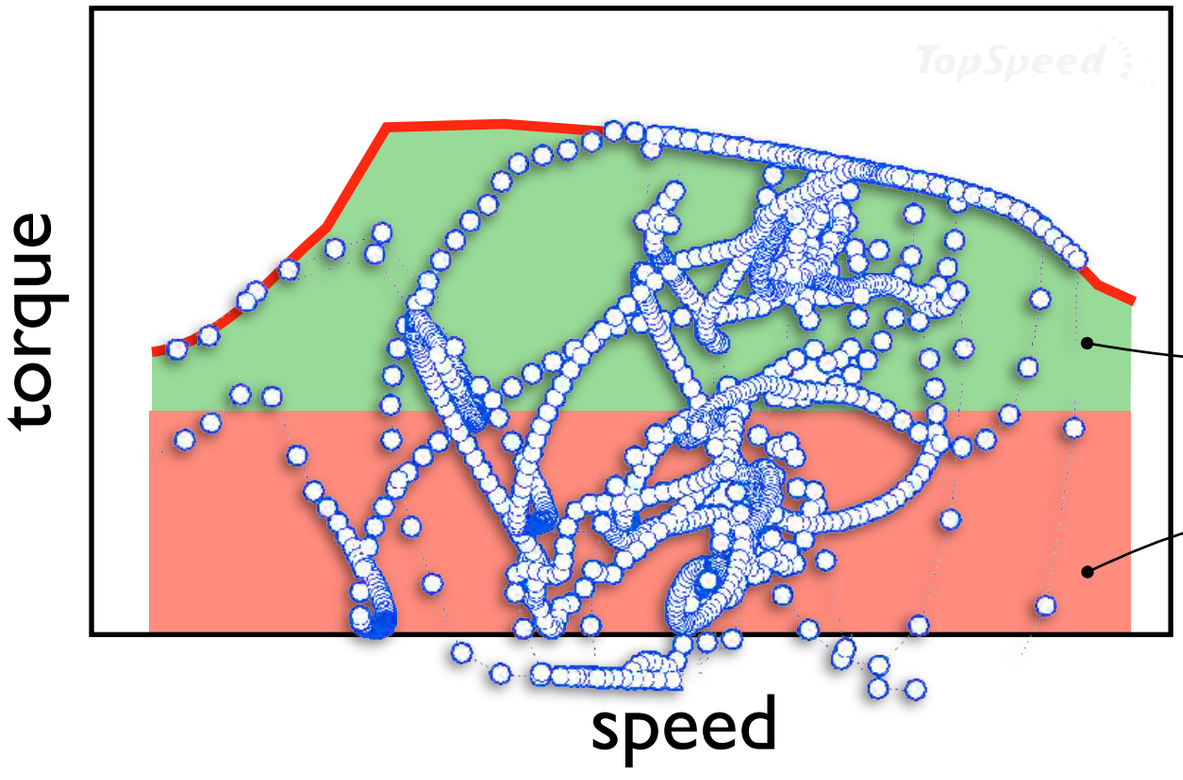
- don’t reduce the performance
- don’t add systems and complexity
- don’t use electric systems and batteries for the main transmission

things you should do:

- replace the mechanical transmission
- avoid throttle losses
- use power management and control
- separate the engine control
  from the load control

engine operation

source: Reno Filla (VCE)



high efficiency

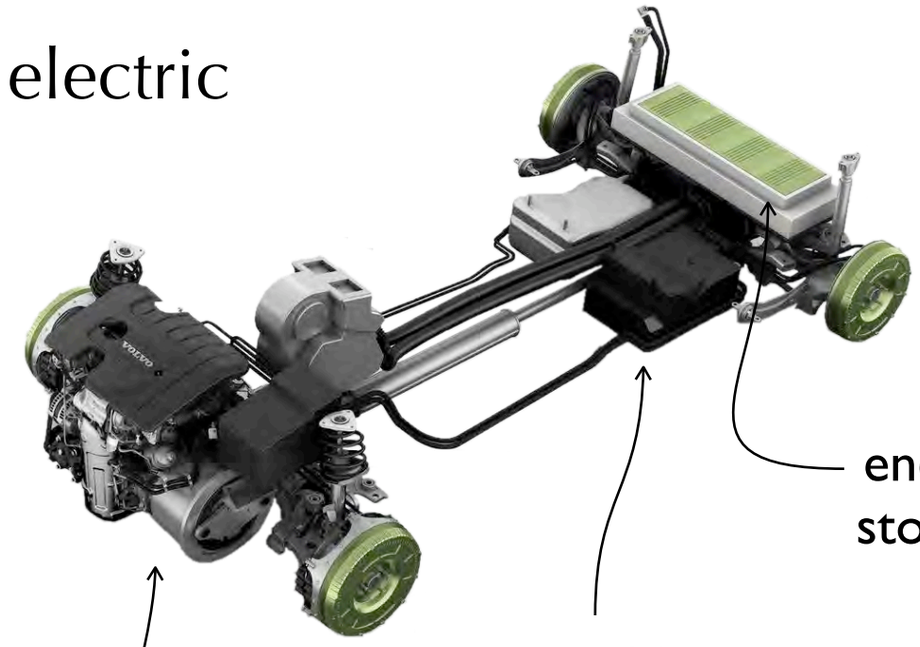
low efficiency

required system lay-out

- introduce a Common Pressure Rail (CPR) with accumulators
- apply hydraulic transmission components (which need to be extremely efficient)
- make the engine run at high loads only
- recuperate energy

Series Hydraulic Hybrid vehicle

series hybrids



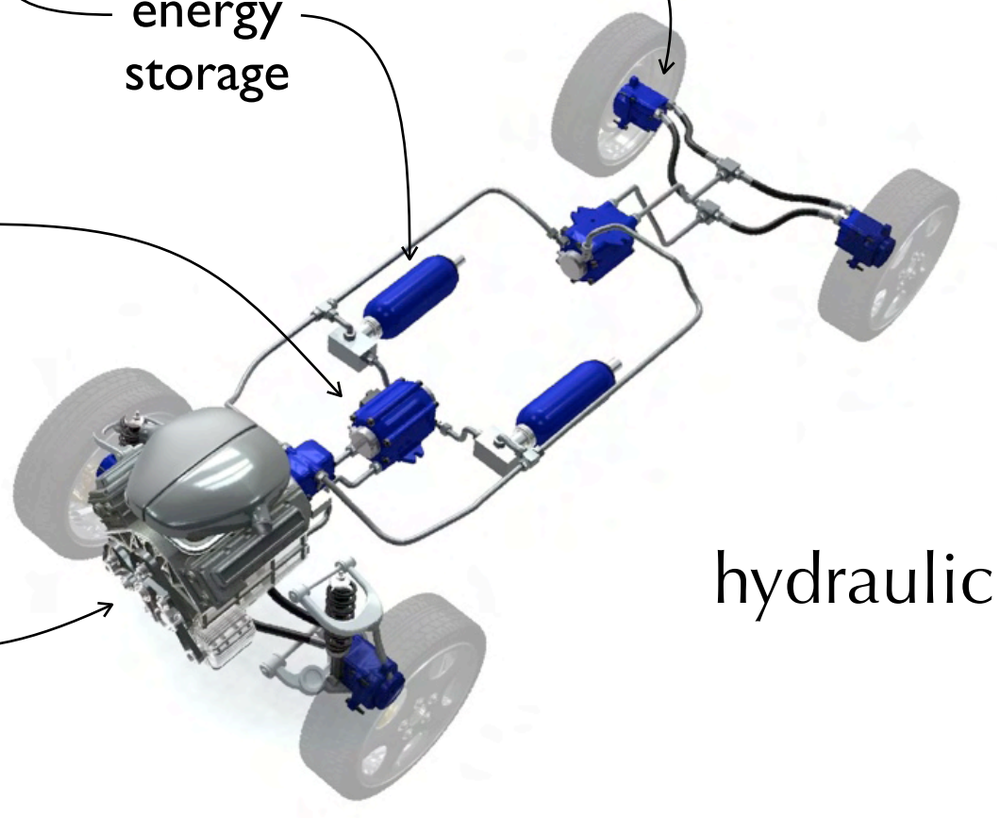
electric

in-wheel motors
in all wheels

energy
storage

power
control

power
plant

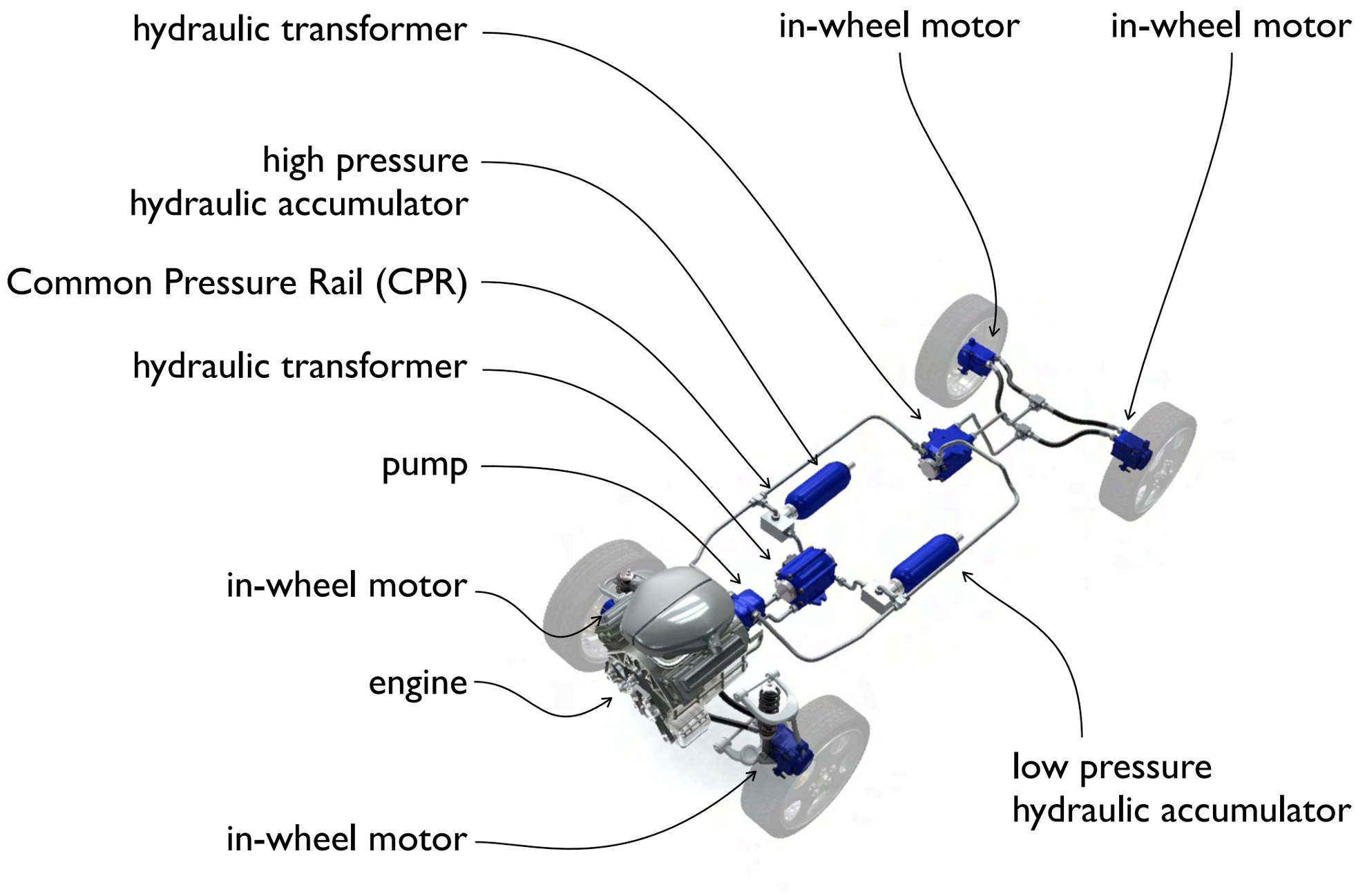


hydraulic

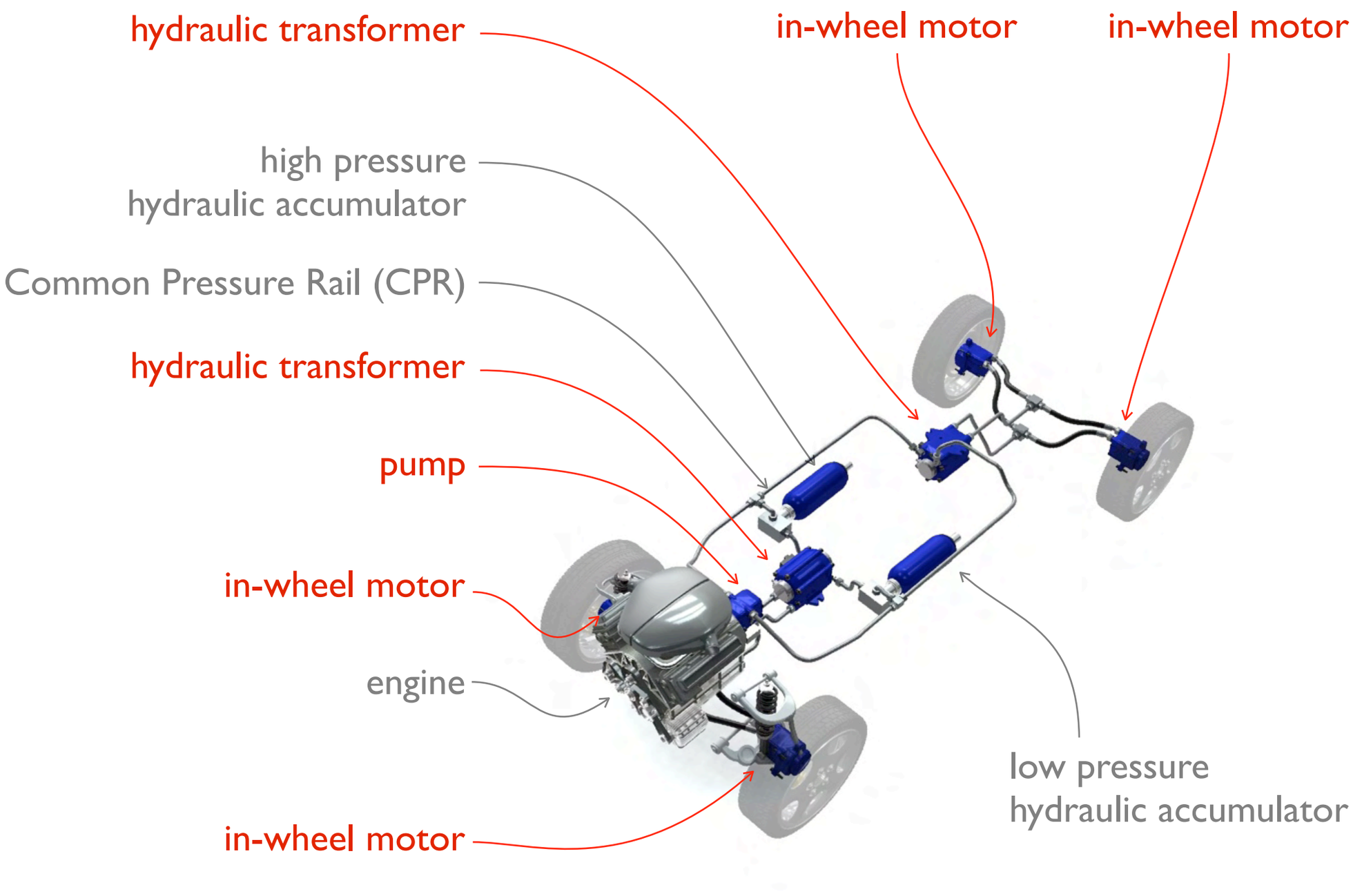
demands transmission components

- high efficiency at normal operating conditions
- high power density
- low manufacturing cost
- in-wheel motors
  - low weight
  - smooth torque
  - low noise, vibration and harshness (NVH)
  - low friction at start-up and low speed
  - four-quadrant operation

Hydrid


hydraulic transformer
high pressure
hydraulic accumulator
Common Pressure Rail (CPR)
hydraulic transformer
pump
in-wheel motor
engine
in-wheel motor
in-wheel motor
in-wheel motor
low pressure
hydraulic accumulator

key components



floating cup principle

- high efficiency
- high torque at start-up
- compact and light
- low pulsation and noise levels
- smooth torque
- low cost
- heavy duty
- low friction & low wear

Innas Hydraulic Transformer

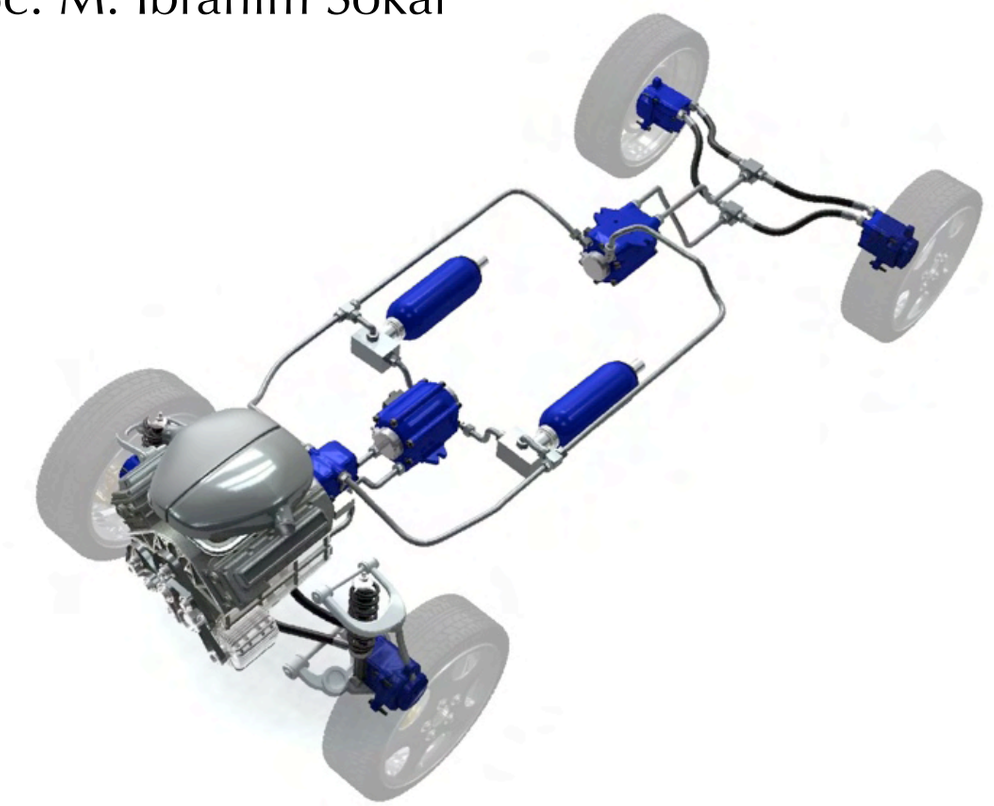
- based on the floating cup principle
- hydraulic “CVT”:
  $(p \cdot Q)_{in} = (p \cdot Q)_{out}$
- high efficiency
- dynamic
- pressure amplification
- energy recuperation

Hydrid

results simulation study

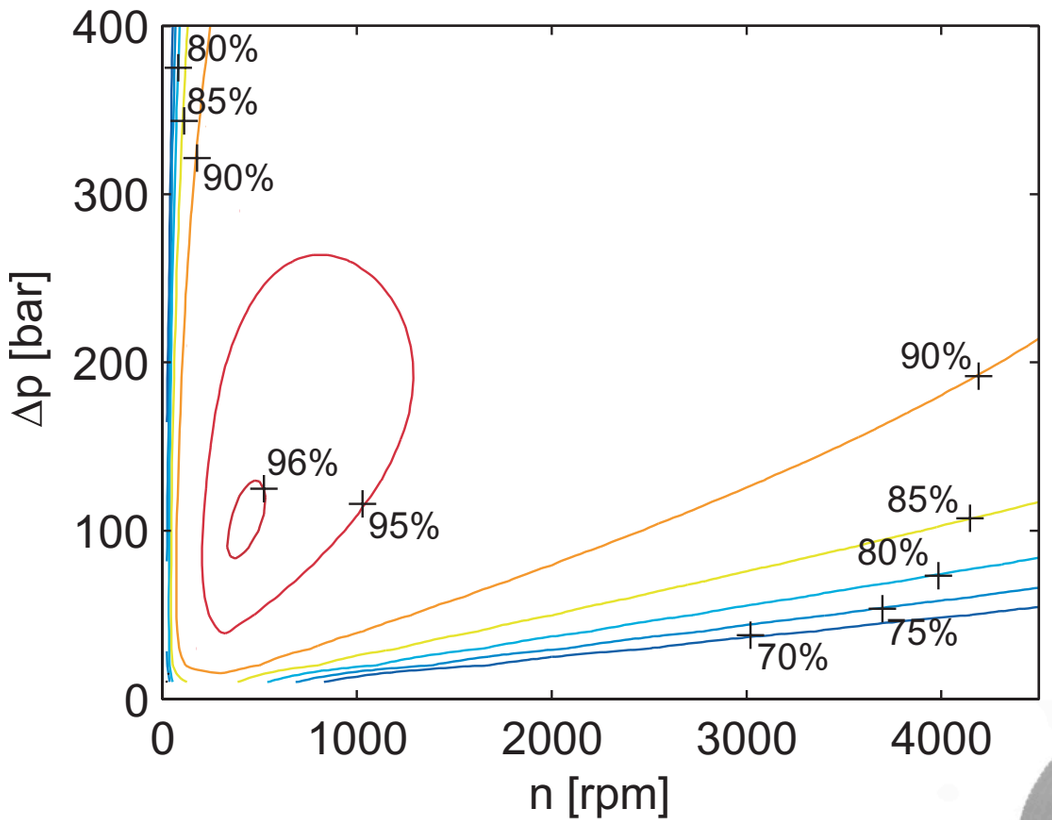
study in co-operation with
the Institute for Fluid Power Drives and Controls (IFAS),
RWTH Aachen University

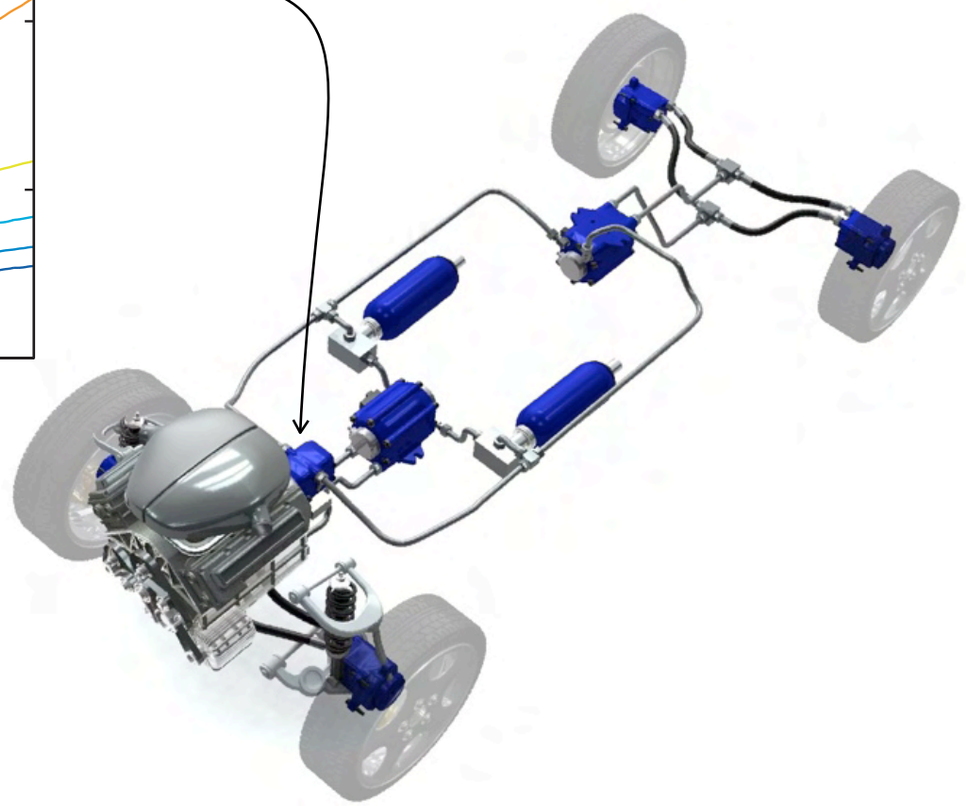
Dipl.-Ing. T. Kohmäscher,
M.Sc. M. Ibrahim Sokar



Hy*d*rid

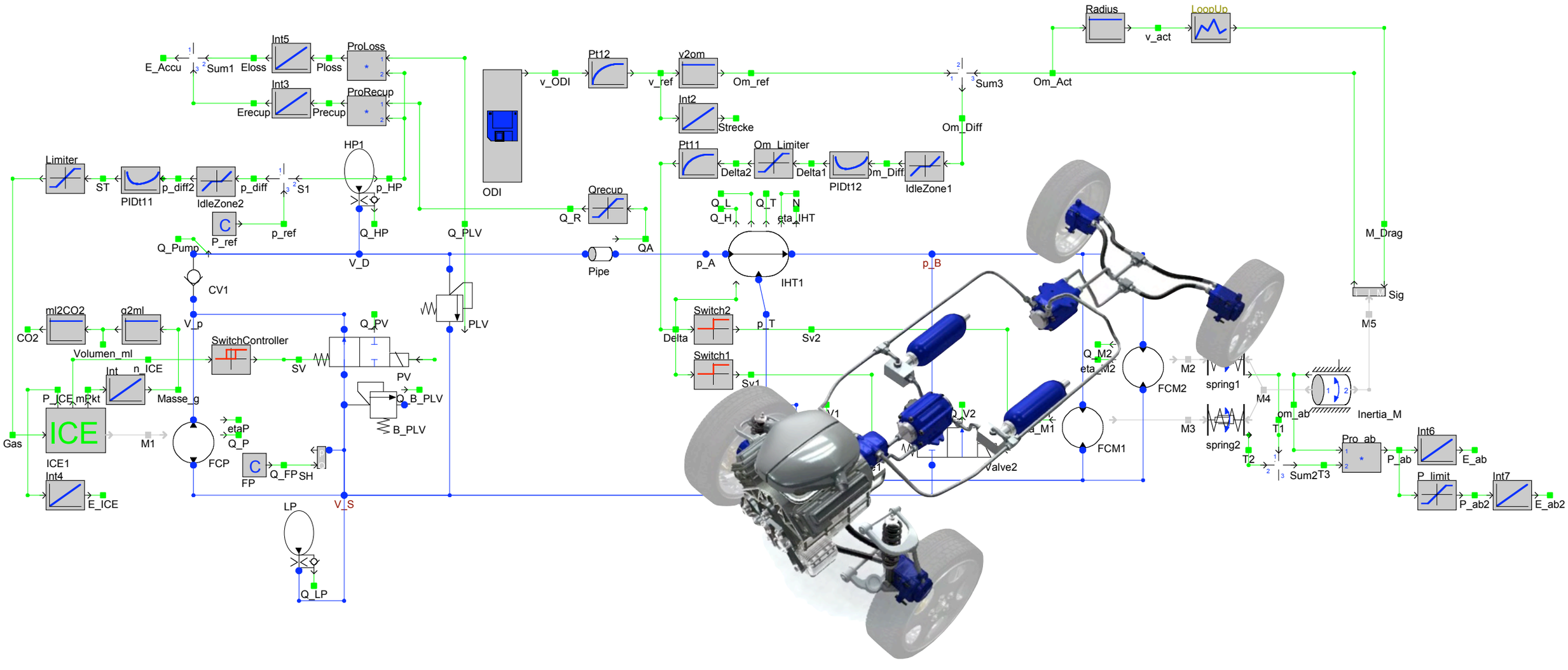
efficiency measurement (IFAS)





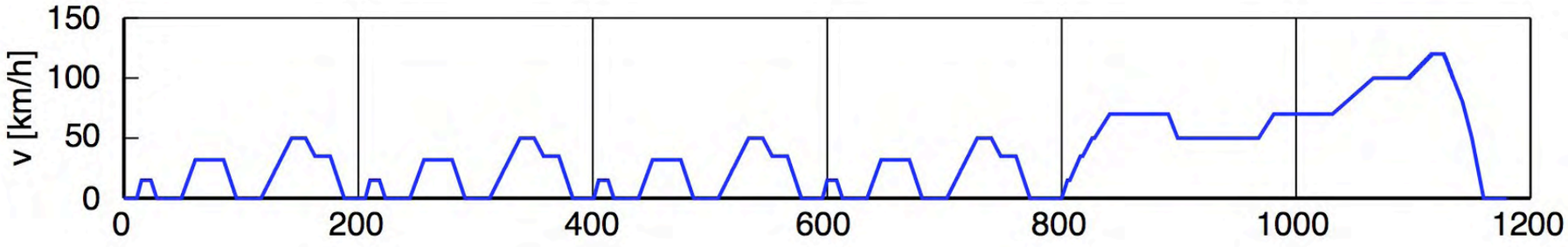
Hydrid

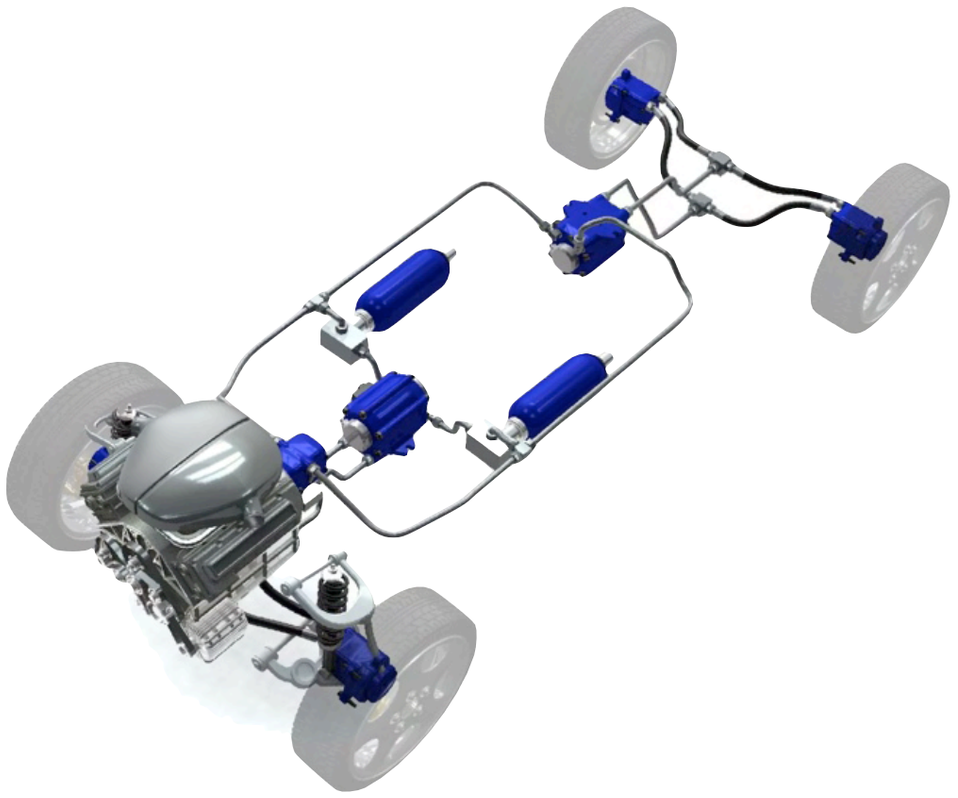
simulation model (IFAS)



Hy*d*rid

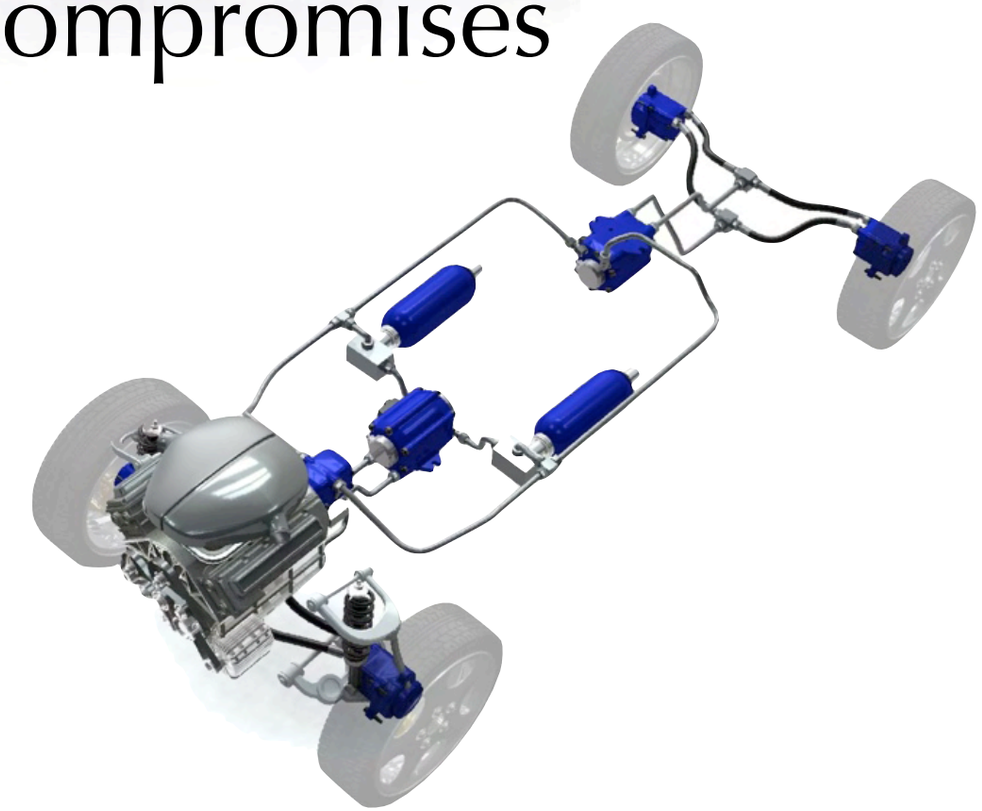
New European Driving Cycle (NEDC)



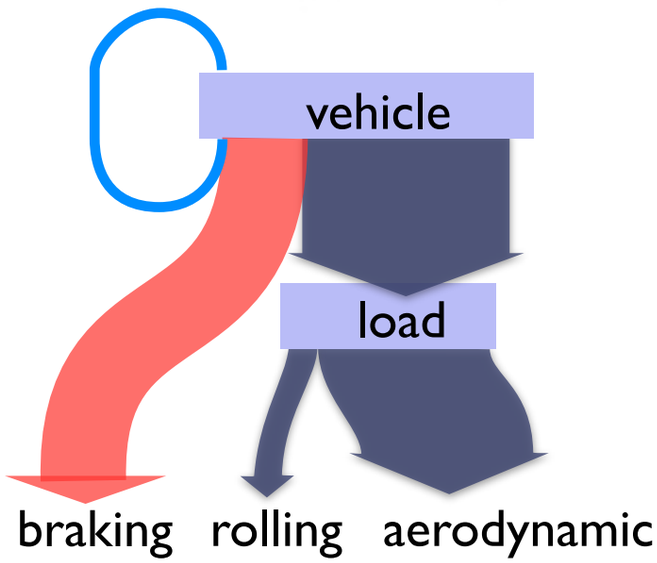


Hydrid

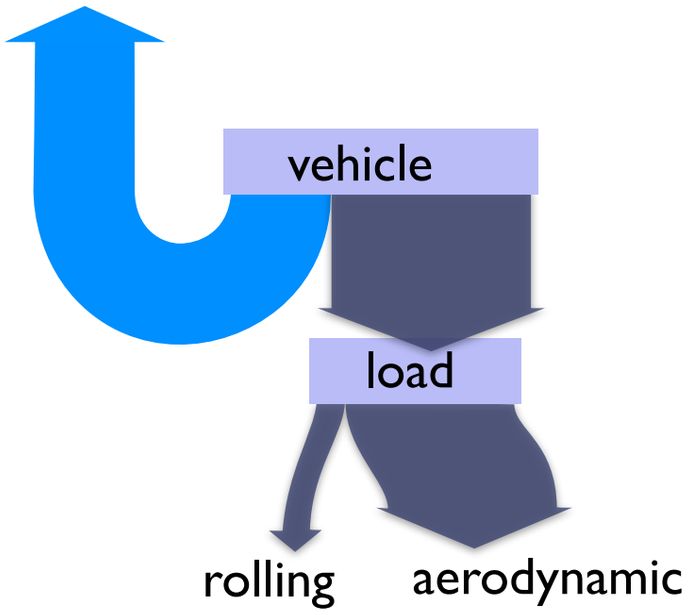
no compromises



fuel consumption

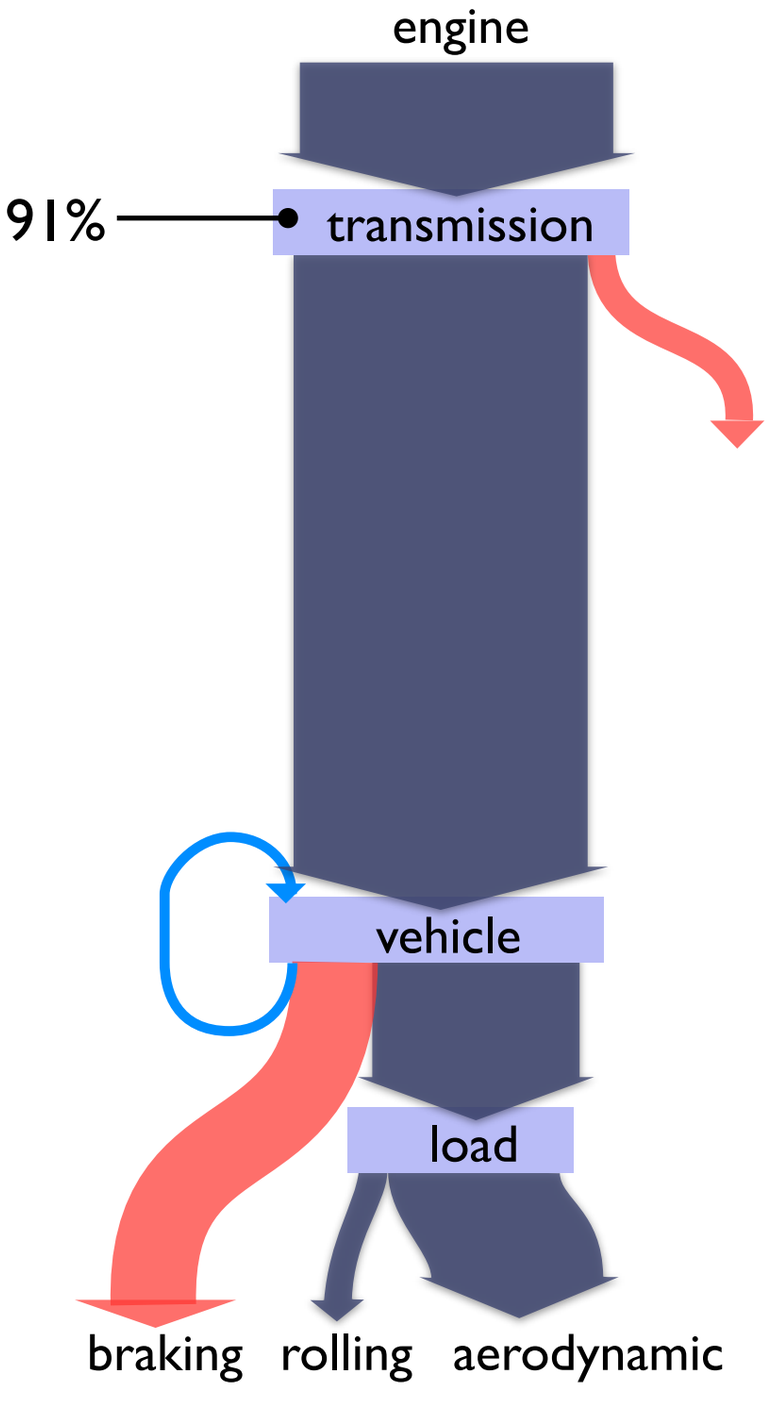


conventional

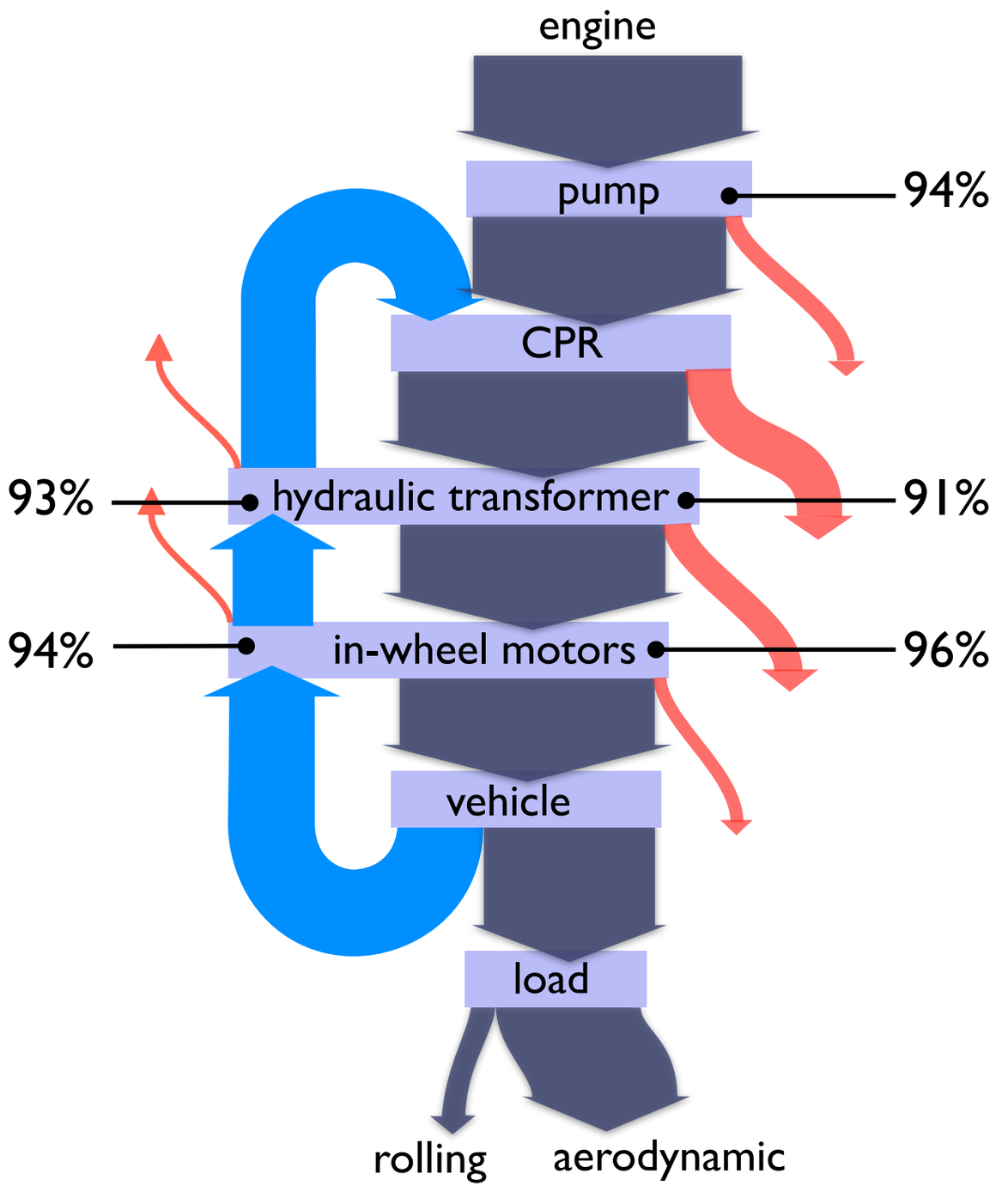


Hy*d*rid

fuel consumption

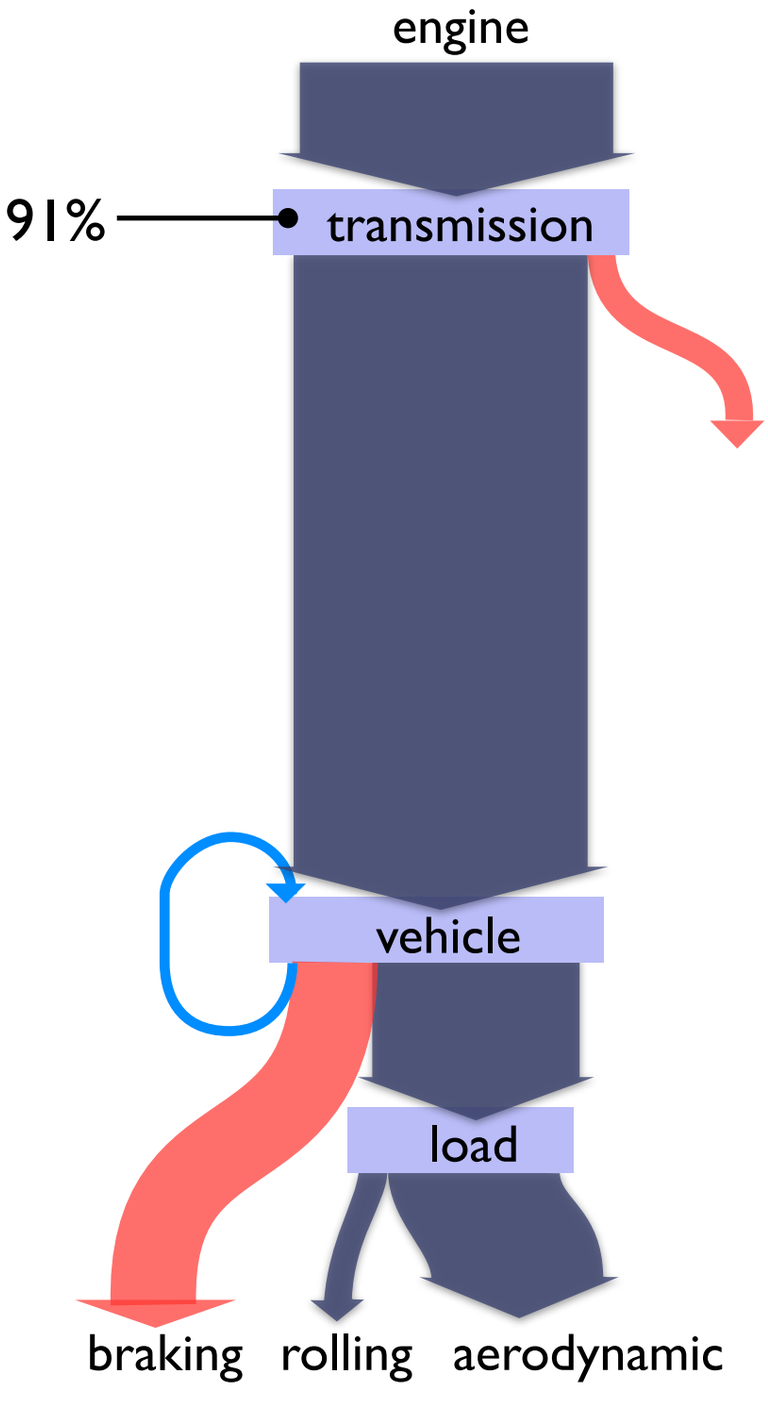


conventional

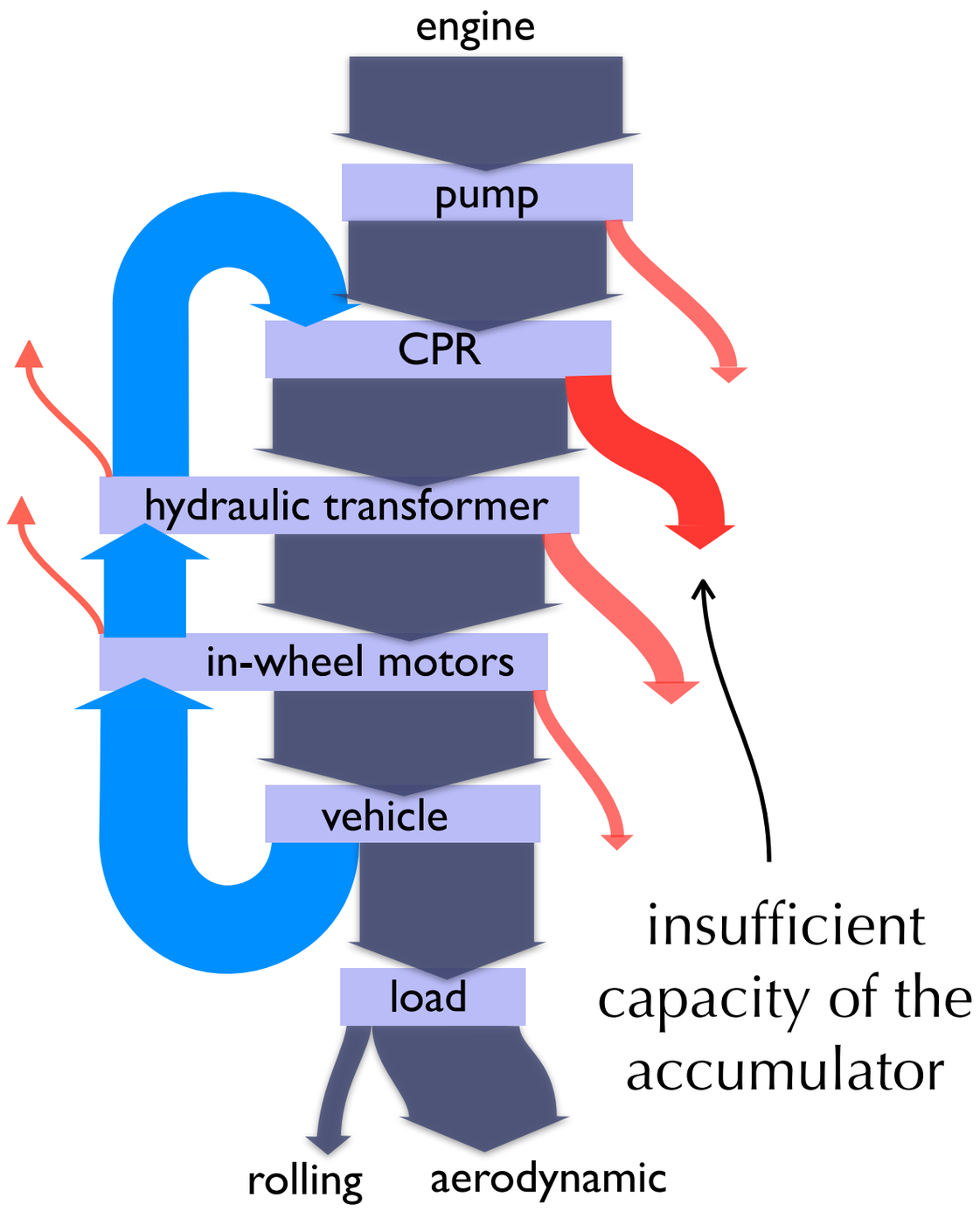


Hydrid

fuel consumption

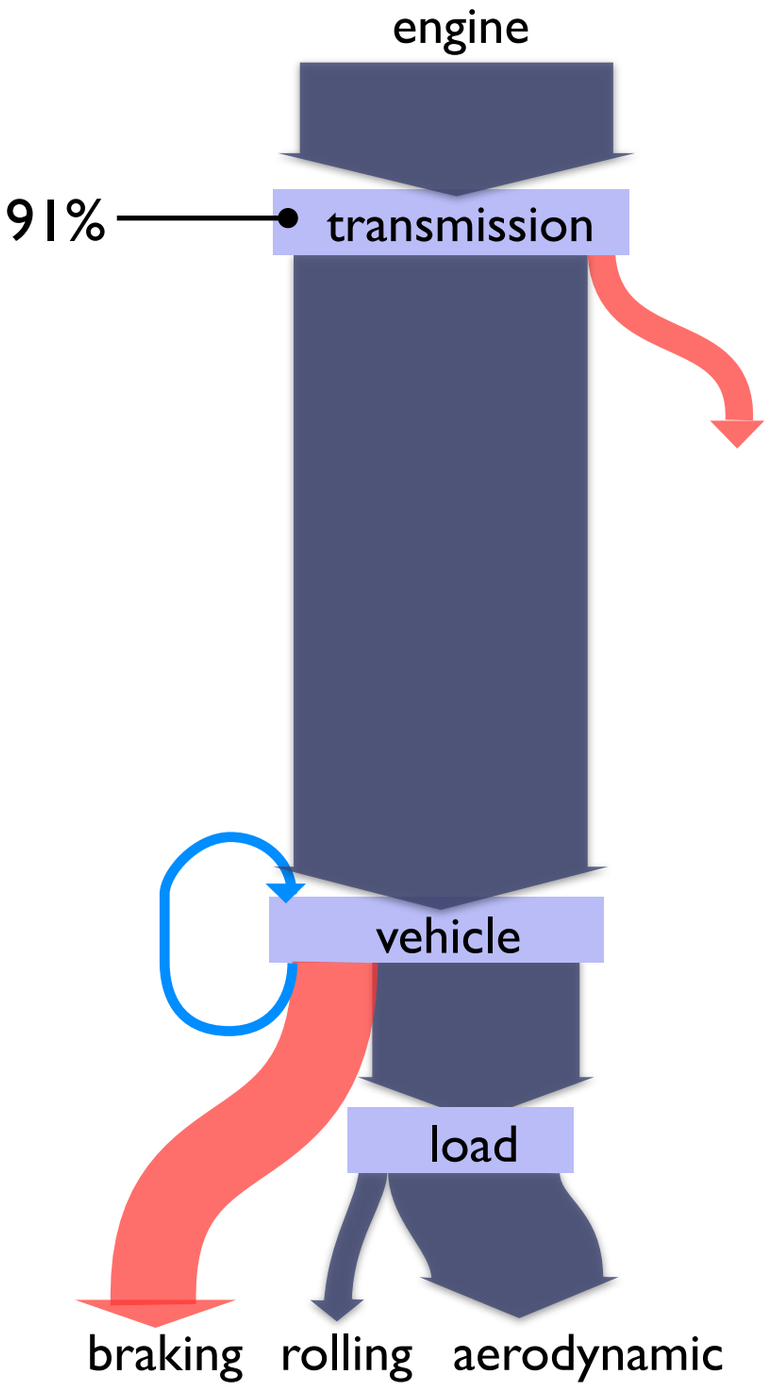


conventional

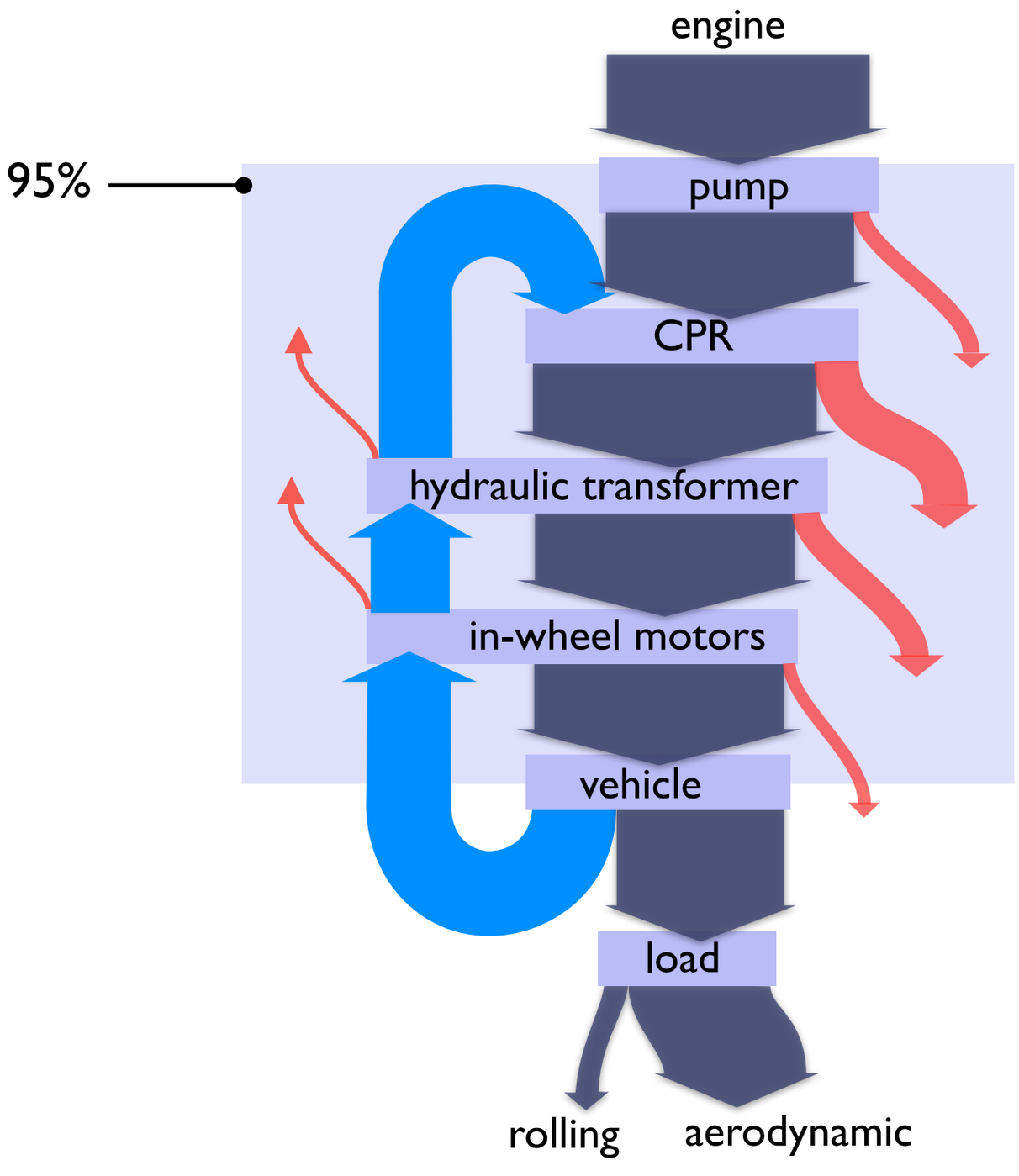


Hydrid

fuel consumption

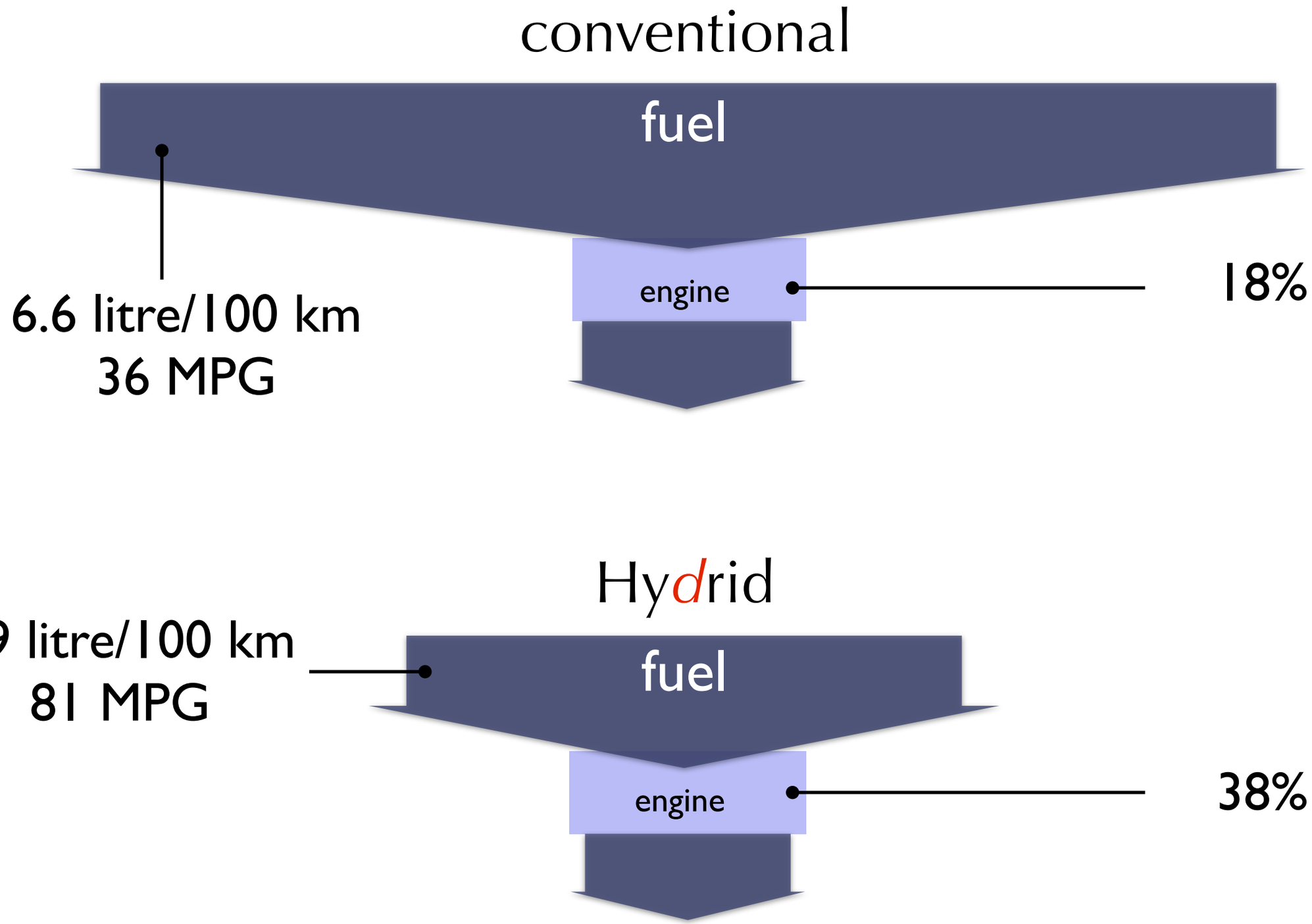


conventional



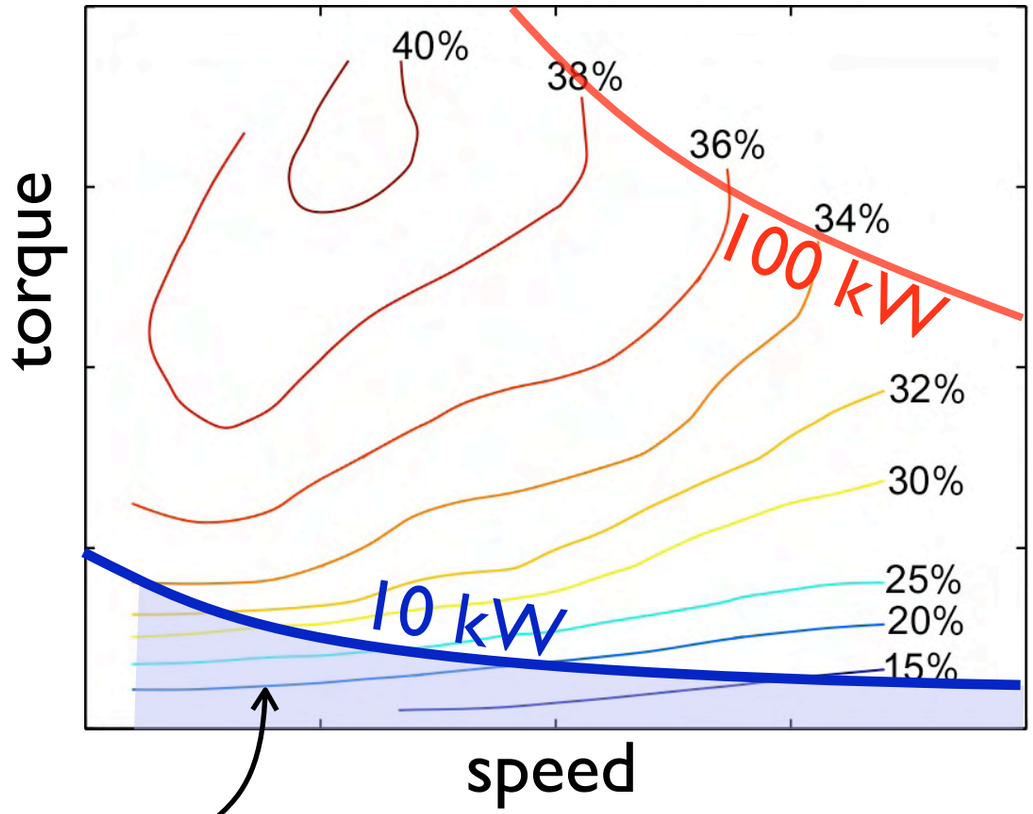
Hydrid

fuel consumption



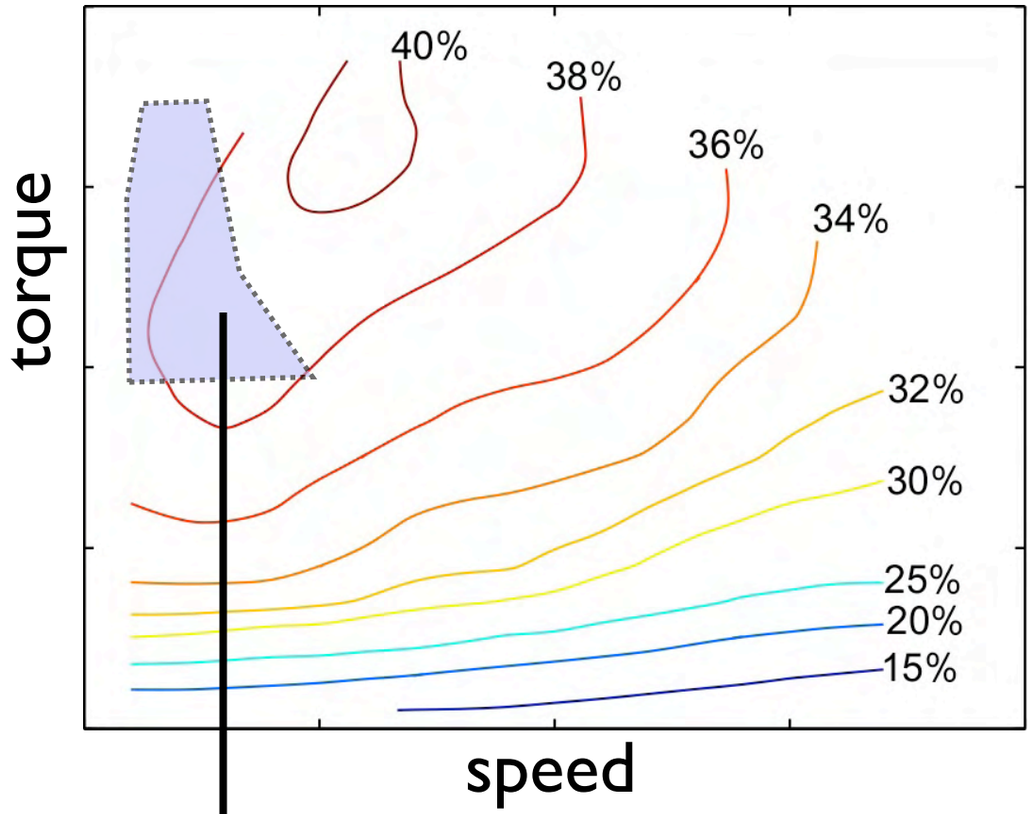
engine efficiency

conventional



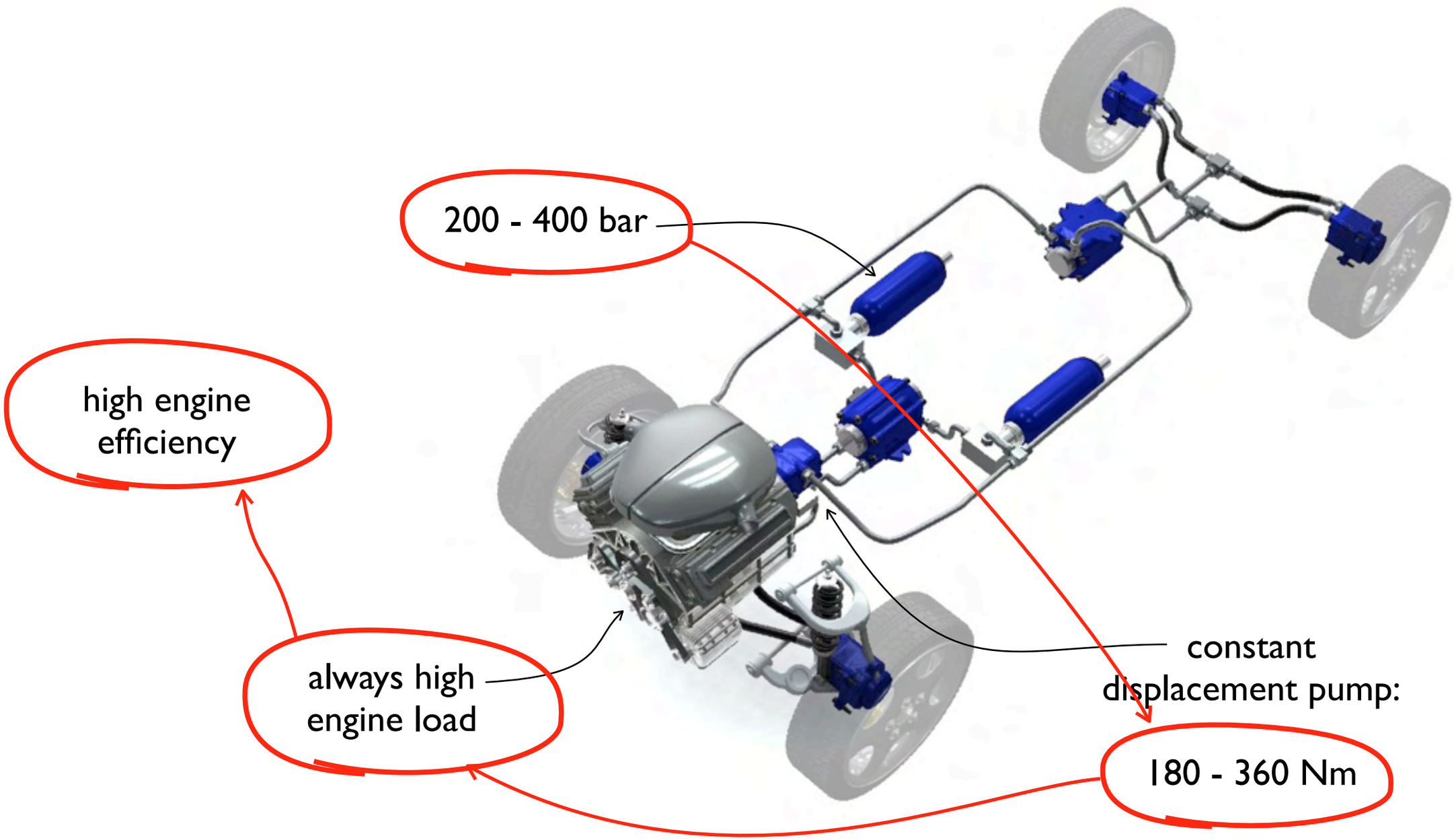
80% NEDC ⟶ efficiency ≈ 18%

Hydrid

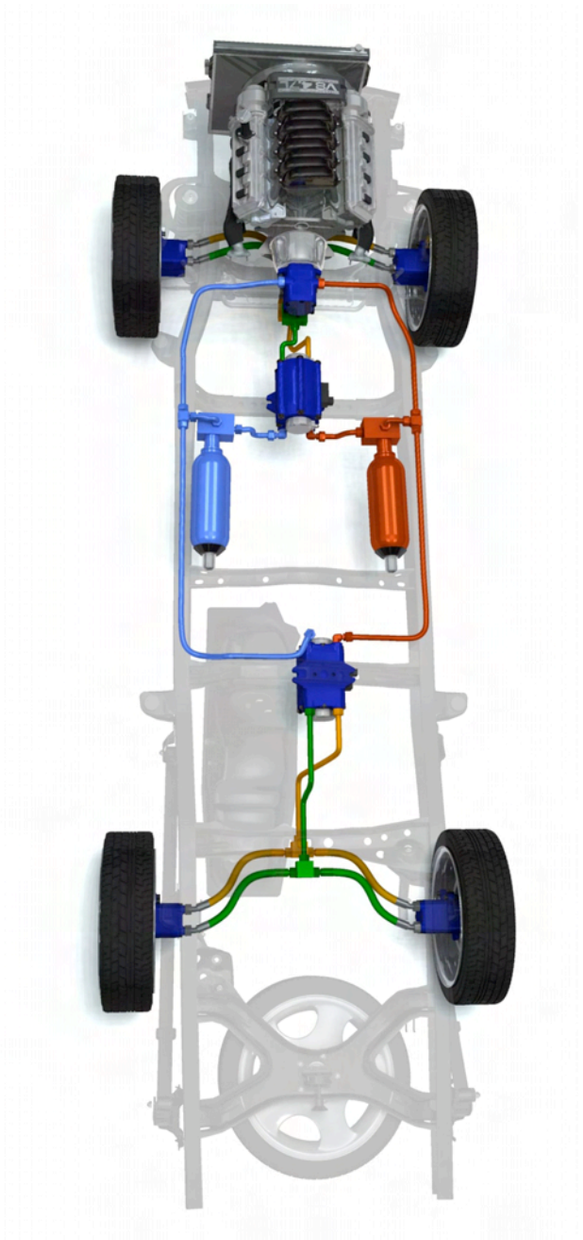


NEDC ⟶ efficiency ≈ 38%

accumulators force the engine to run at high efficiency

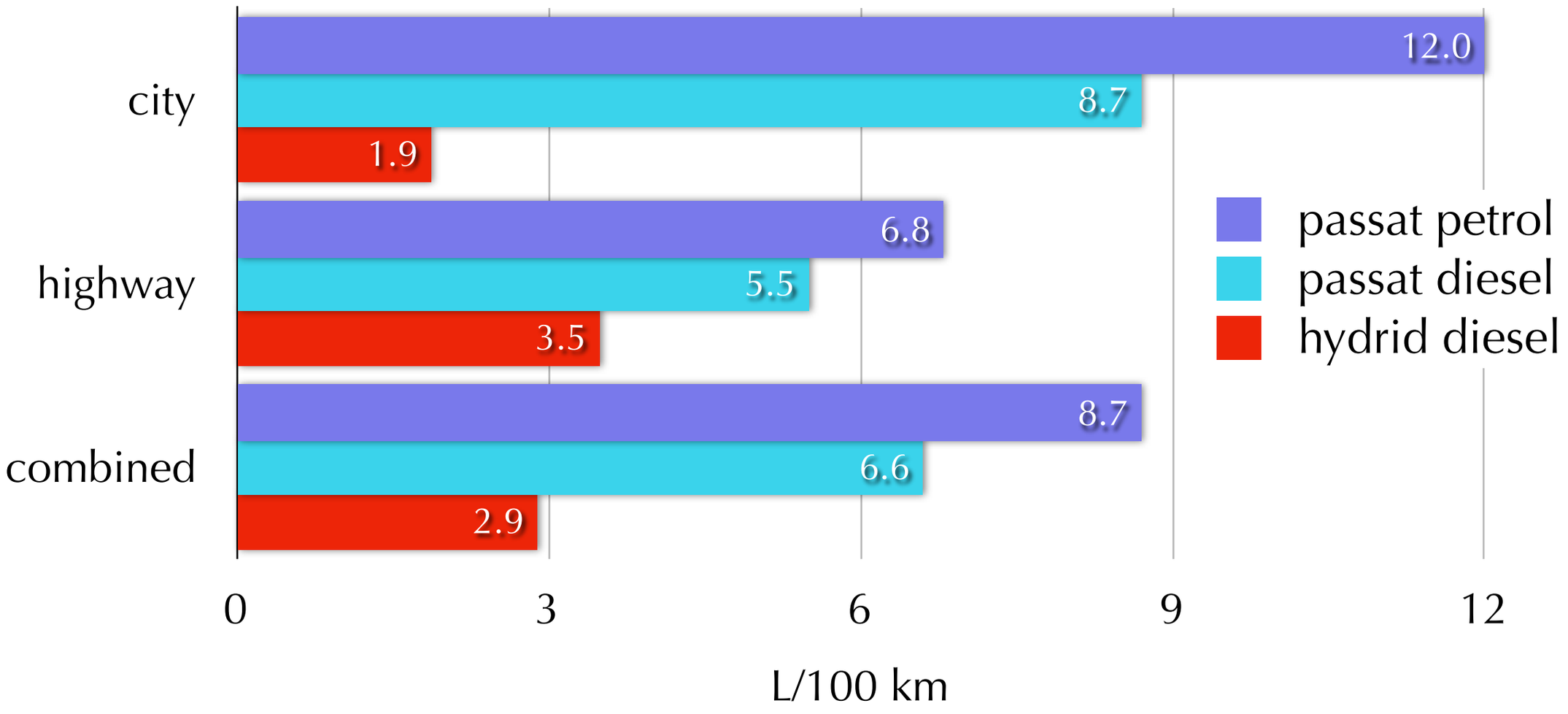


fuel consumption and CO_2-emissions



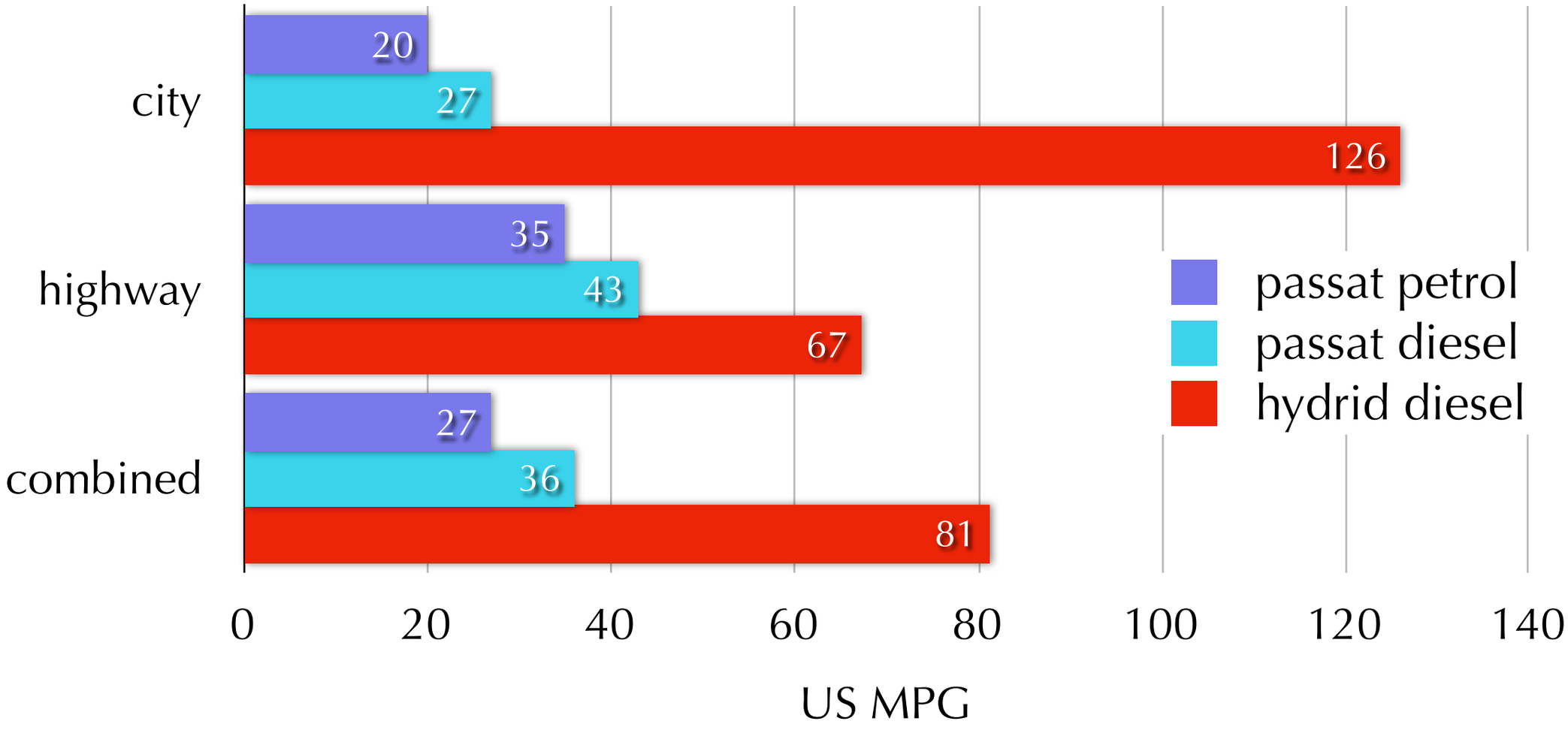
fuel consumption

4-wheel drive, 100 kW, NEDC (litre/100km)



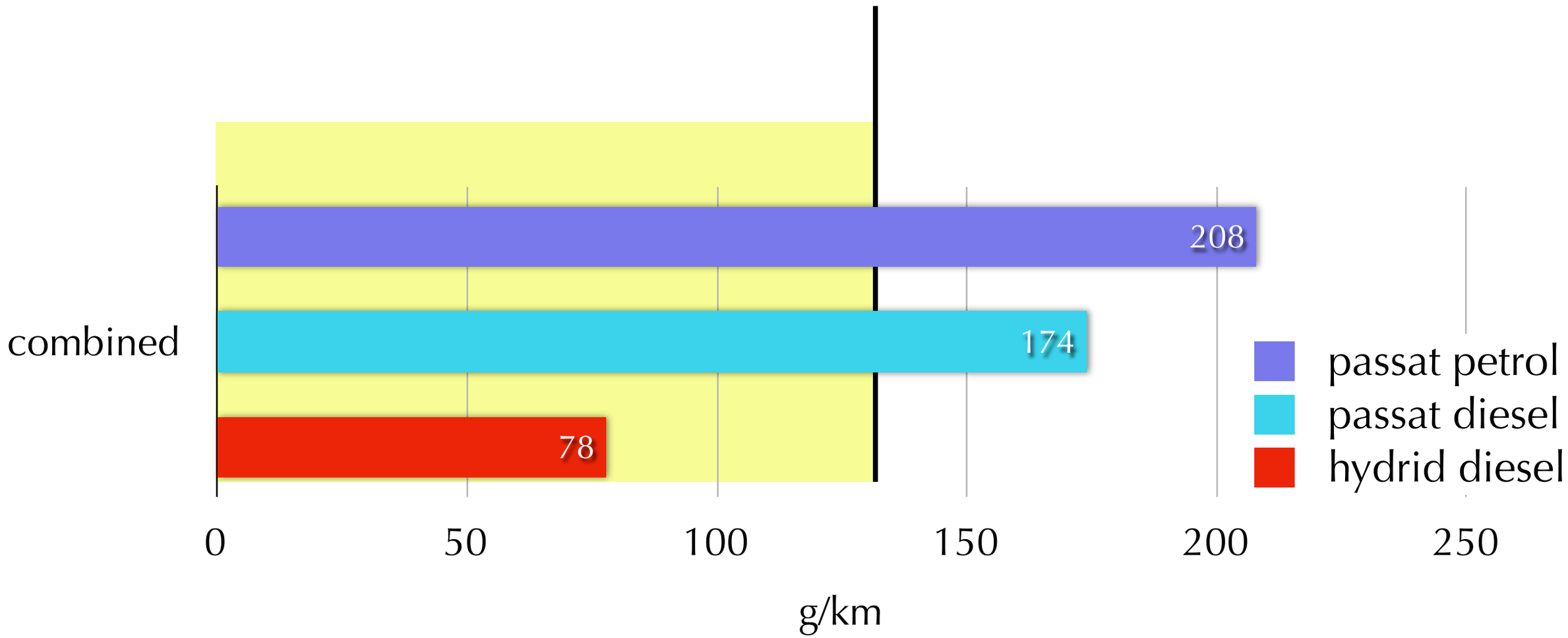
fuel consumption

4-wheel drive, 100 kW, NEDC (US MPG)



CO_2-emission

4-wheel drive, 100 kW, NEDC (gram/km)



conclusion

conventional

6.6 litre/100 km

Hy*d*rid

3.1 litre/100 km

same car

same cycle

same performance

same weight

same traction

< 50% fuel consumption

< 50% CO_2-emission

same concept can be applied in construction equipment