OVE SPONTÓN – SENIOR TECHNICAL ADVISOR, PROPULSION DEVELOPMENT

EV TRANSMISSIONS

2025-01-09

SCANIA

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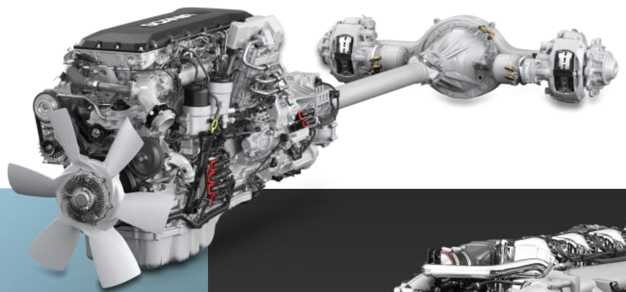
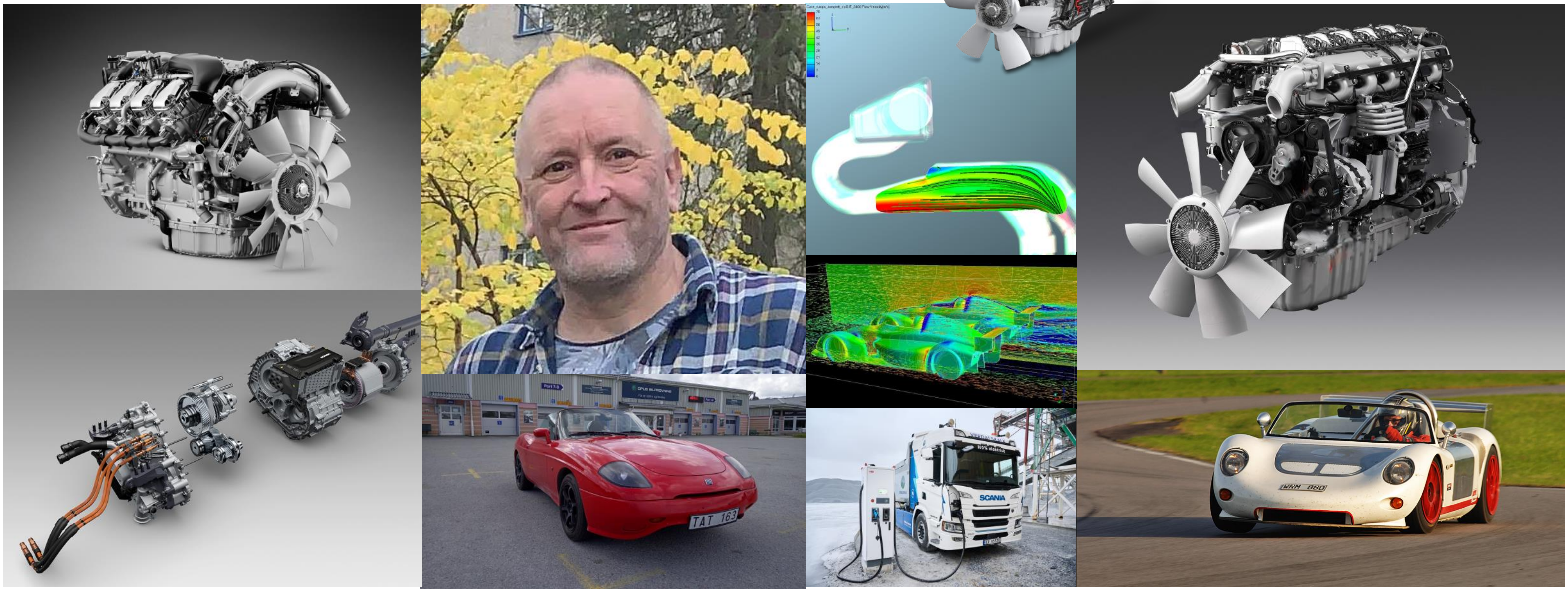
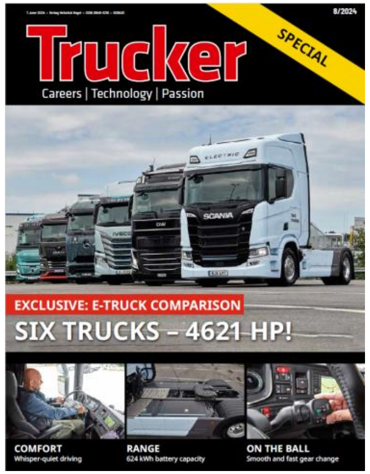
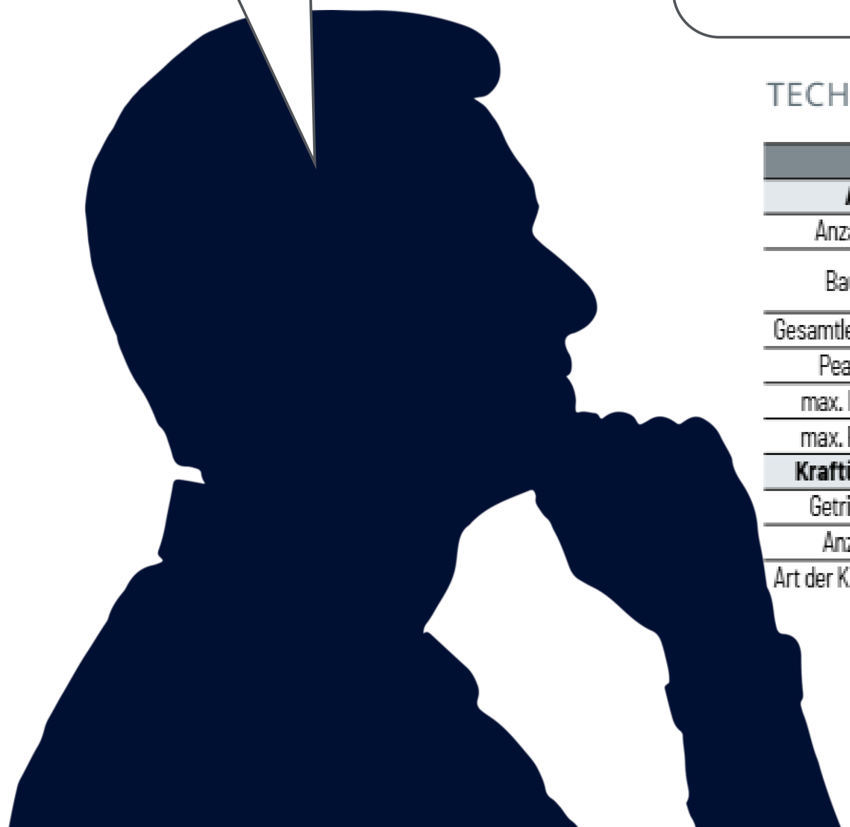




How to evaluate EV performance? What does the numbers really mean?





What about startability?

The truck with the highest power rating has the second lowest torque?

How to evaluate peak versus continous power?

TECHNISCHE DA

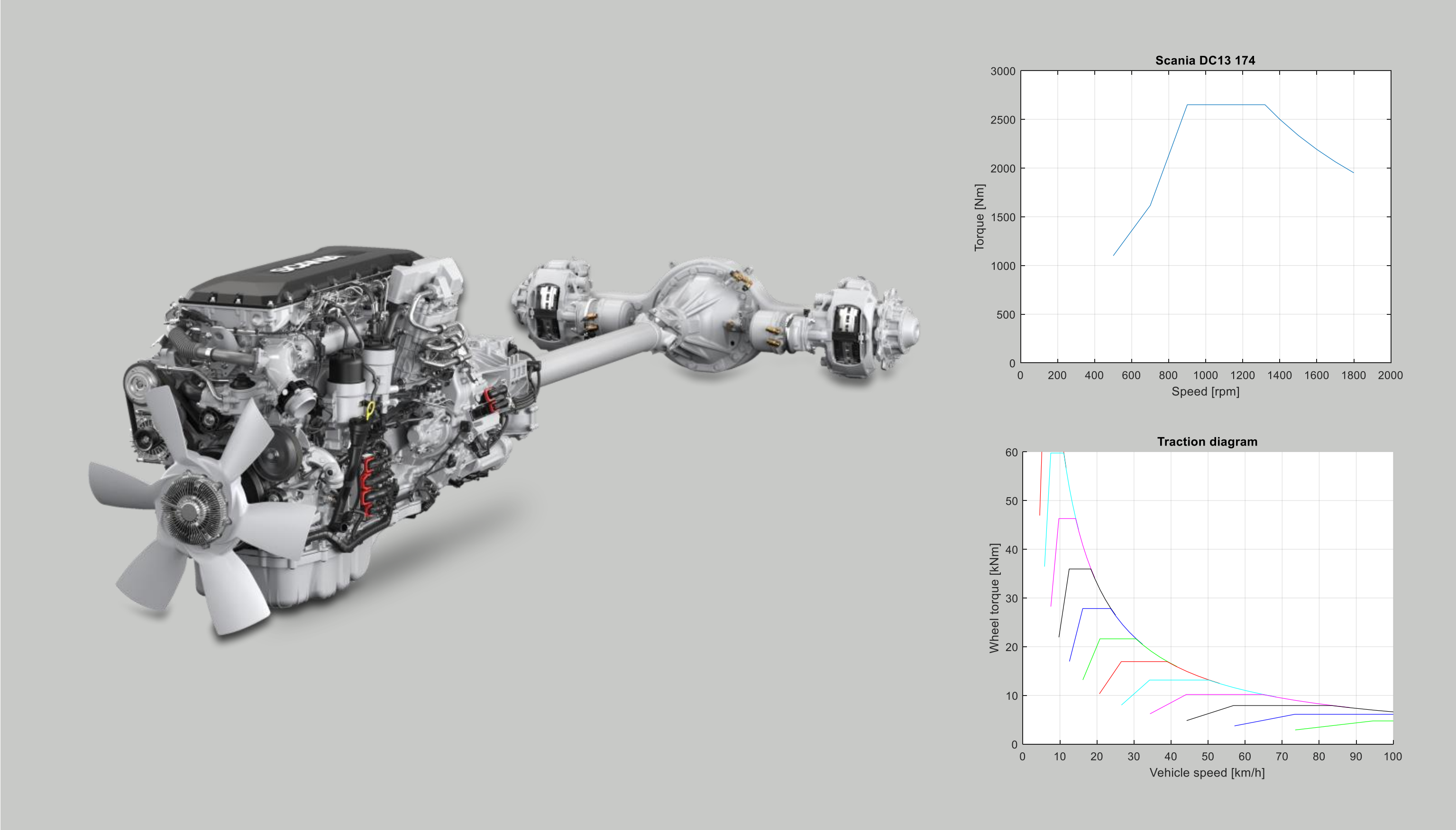
	De[illegible]r	Iveco	MAN	MB	Scania	Volvo
Antrieb						
Anzahl Motoren	4	2	1	2	3	3
Bauart Motor	Synchron-E-Motoren	Synchron-E-Motoren, Permanent-Magnet	Synchron-E-Motoren	Synchron-E-Motoren, permanent erregt	Synchron-E-Motoren	Synchron-E-Motoren
Gesamtleistung konstant	500 kW (680 PS)	480 kW (653 PS)	330 kW (449 PS)	400 kW (544 PS)	450 kW (612 PS)	490 kW (666 PS)
Peak-Leistung	/	840 kW (1142 PS)	/	628 kW (854 PS)	500 kW (680 PS)	600 kW (816 PS)
max. Drehmoment	k. A.	1800 Nm	1150 Nm	k. A.	3500 Nm	2400 Nm
max. Rekuperation	500 kW	600 kW	330 kW	628 kW	600 kW	400 kW
Kraftübertragung						
Getriebe verbaut	nein	nein	ja	ja	ja	ja
Anzahl Gänge	-	-	4	4	5	12
Art der Kraftübertragung	Kardanwelle	E-Achse	Kardanwelle	E-Achse	Kardanwelle	Kardanwelle

Passenger cars only have one gear?

How to compare EV vs ICE

We are familiar with reading spec sheets on the conventional drive train. The engines speed ranges are all in the same region, power and torque values are familiar and easy to interpret.

The vehicles total performance is dictated by the wheel torque diagram.



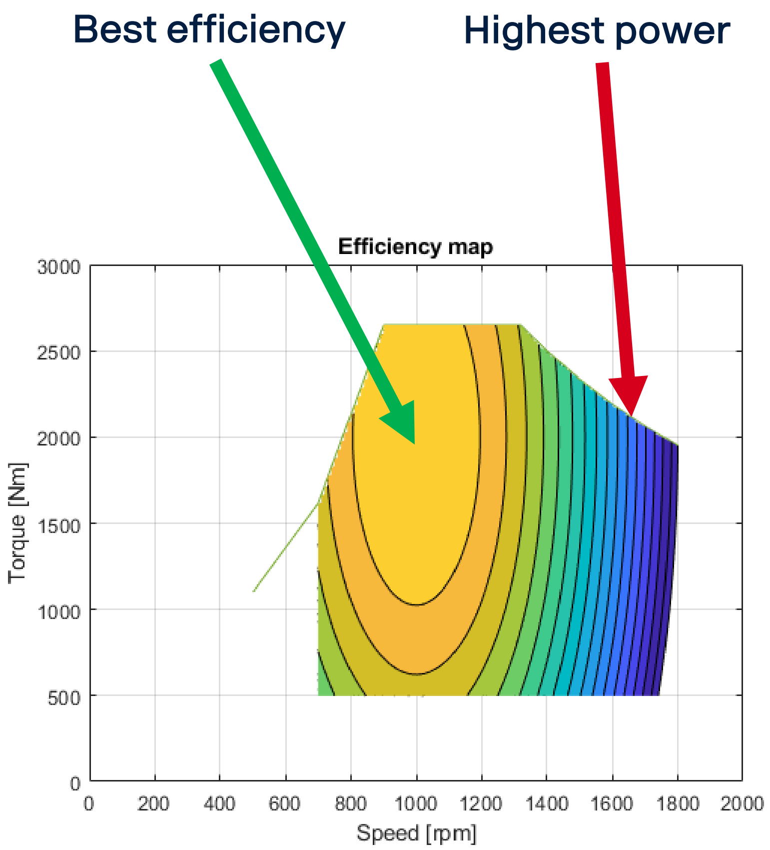
How to compare EV vs ICE

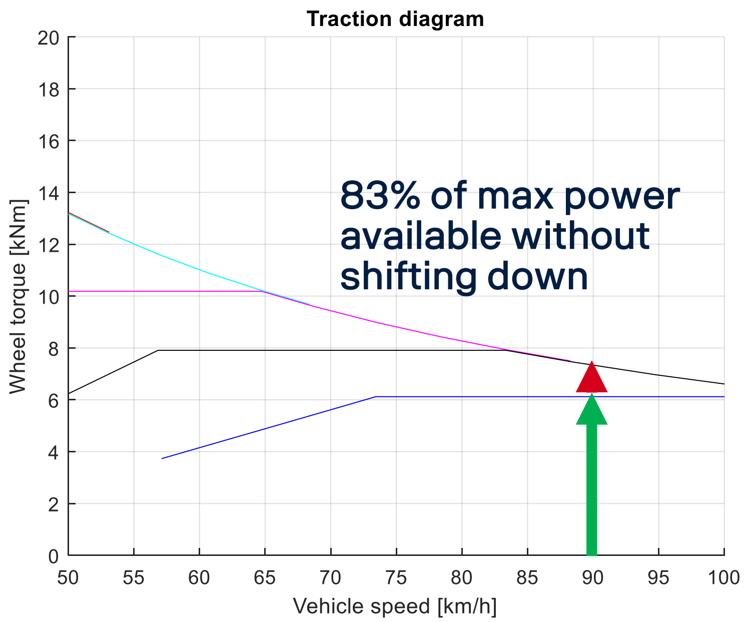
ICE reference DC13 174, 500 hp, 2 650 Nm

The speed regime for best efficiency and max power differs.

This means that selecting gear will be a compromise between fuel consumption and performance

High torque to power ratio is beneficial booth from a drivability perspective and efficiency.

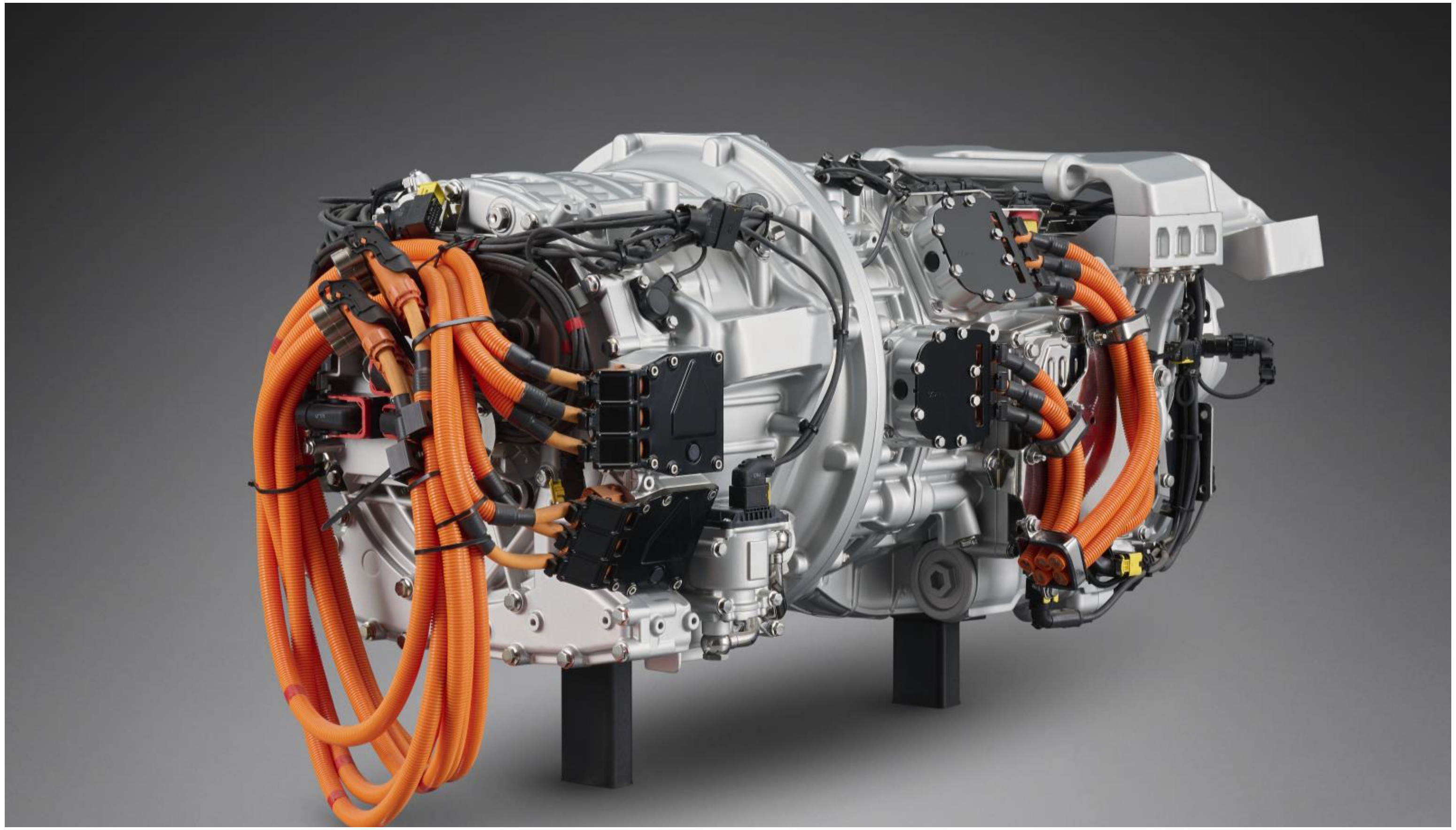




How to compare EV vs ICE

What parameters to look for in an EV powertrain?

To understand what properties that are important, we need to understand a bit more about the electric motor.



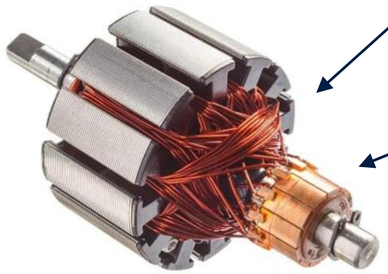
Short on DC motors

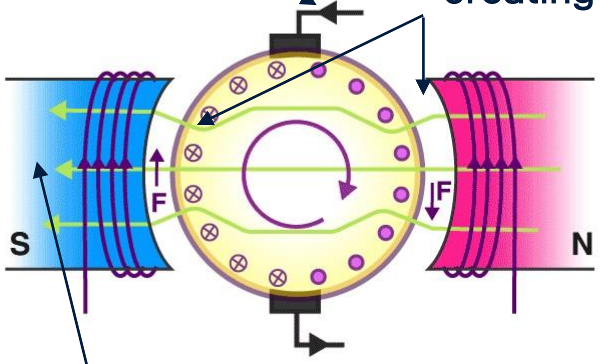
Plus points being that the DC motor is both easy to understand and build.

The DC motor has some properties making it less ideal as a traction motor in a commercial vehicle such as:

- Low power density
- Low lifelength
- Not the best efficiency
- Hard to cool

Not used as propulsion motors in CV’s.





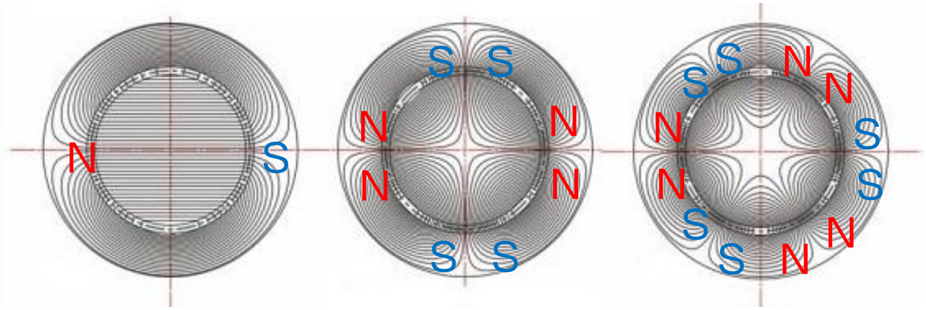
Not as short on AC motors

The basis for most AC motors is the stator.

The stator creates a magnetic field that is rotating by a speed dictated by the AC frequency.

The pole-number tells how many N/S pole pairs that is created. This is dictated by the winding scheme of the stator.

Since the stator windnings are fed by an AC current the magnetic field will rotate.



Not as short on AC motors

Inside the stator a rotor is placed.

The type of rotor sets the main characteristics of the motor.

The reluctance and magnetic motors are synchronous whilst the induction motor is asyncronous.

Meeting the requirements on power density and efficiency a magnetic rotor is needed.

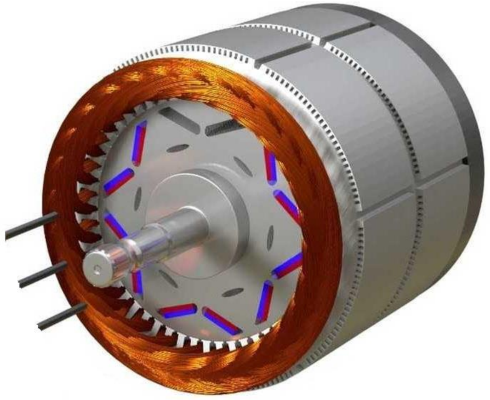
A synchronous PM-motor is the state of the art.

This does however **not** mean that all PM-motors are the same. All commercial diesel engines are 4-stroke piston engines, but they differs a lot. The devil is in the details and the same applies for the PM-motor.

Reluctance

Induction

Permanent Magnet

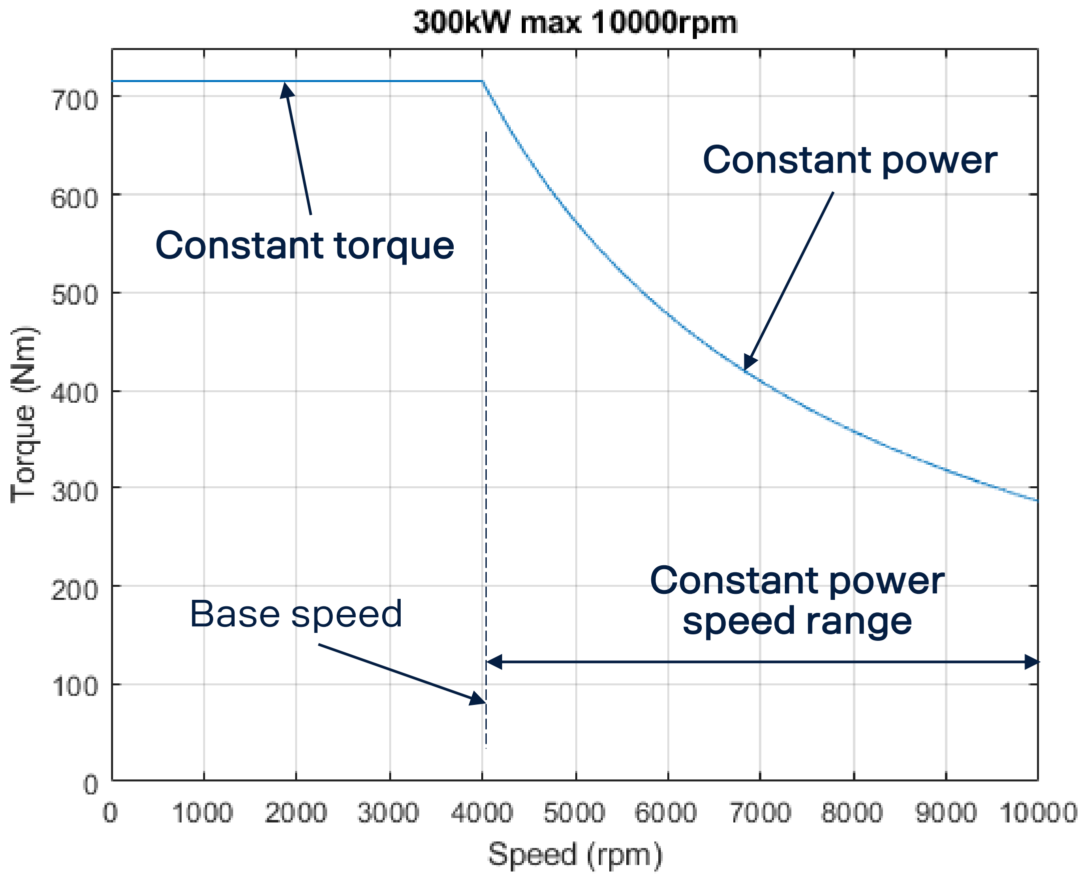


Synchronous PM motor characteristics

The PM motor has a torque plateu with a constant torque mainly being limited by maximum current.

At base speed the voltage generated by the spinning motor reaches the battery voltage level. From this point active field weakening is needed.

As speed increases more and more of the available current is used for field weakening giving a constant power above the base speed.

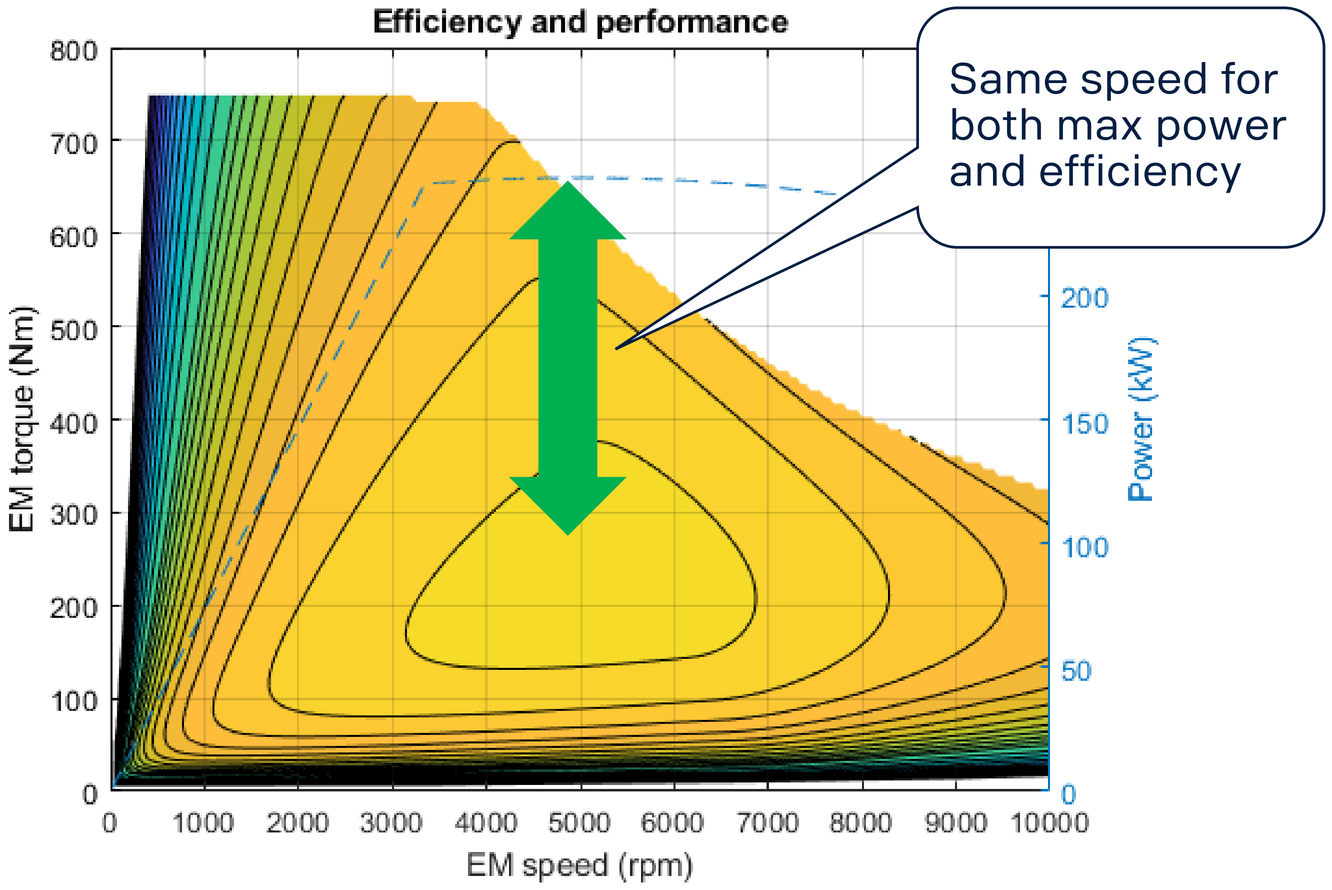


Synchronous PM motor characteristics

Speed range for power and efficiency coincides.

The width of the power band is measured as a ratio between max and min speed where close to max power is achieved. Normally this ratio is in the region of 2.5–3.5

When selecting gear, there is no need to compromise between efficiency and power.



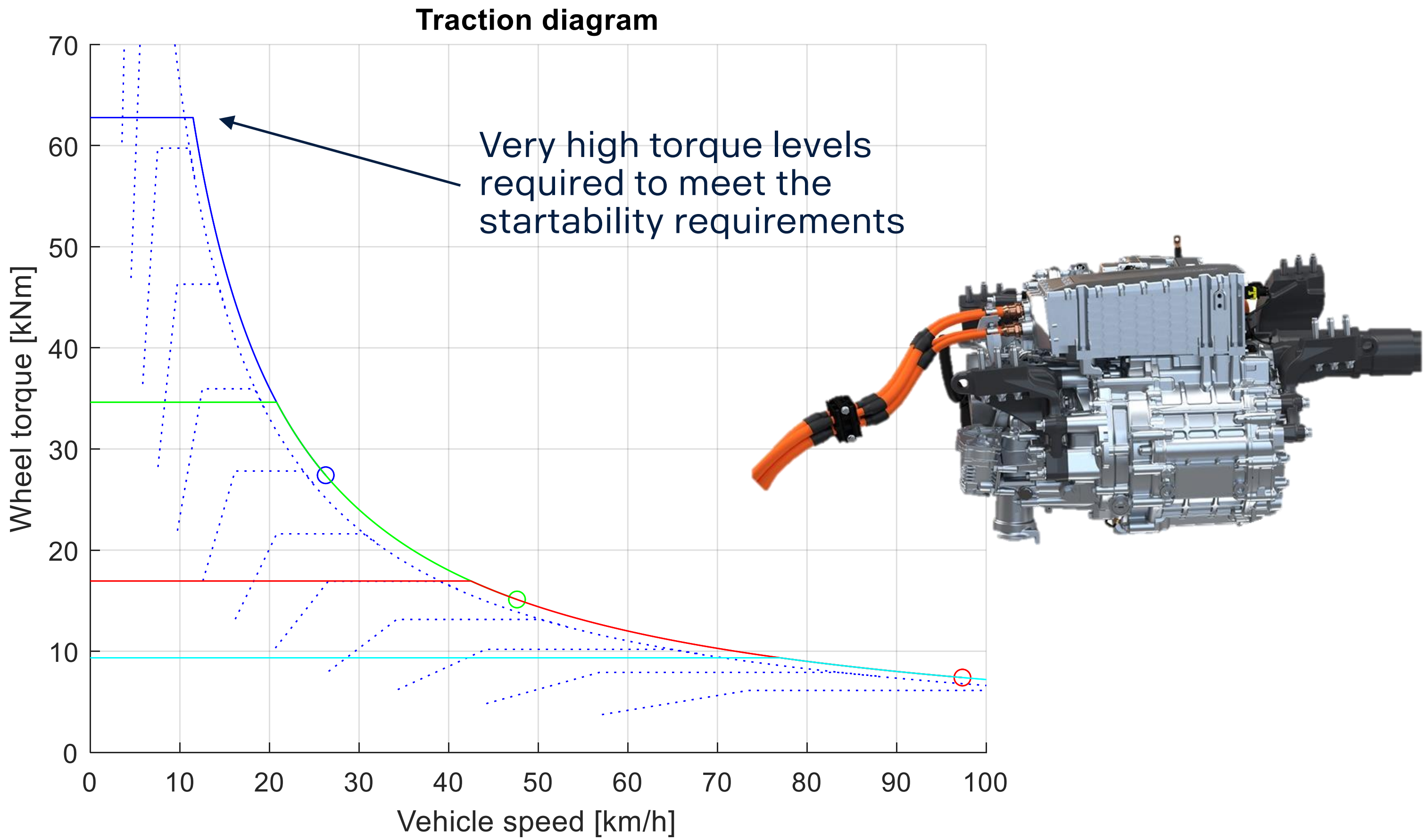
How to compare EV vs ICE

EMC1-4 400 kW 4sp vs DC13 174 500 hp

Speed range with full power requirement is way above a factor of 10.

More than one gears or more motors attached with different ratios is needed to match the requirement for a heavy vehicle.

Meeting the starting and top speed, with less than three gears is challenging.



Are really several gears the only solution?

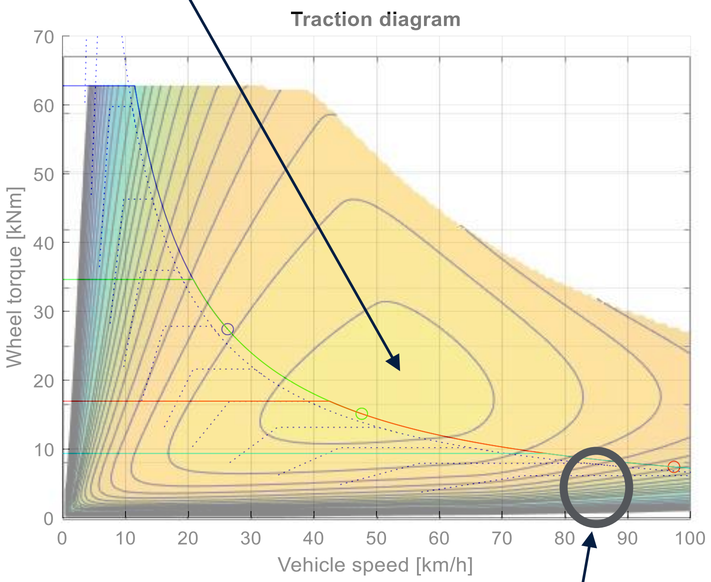
Oversizing the electric motor covers the entire performance envelope with one single gear step.

However, there will be a poor match between the efficiency characteristics and where energy is consumed.

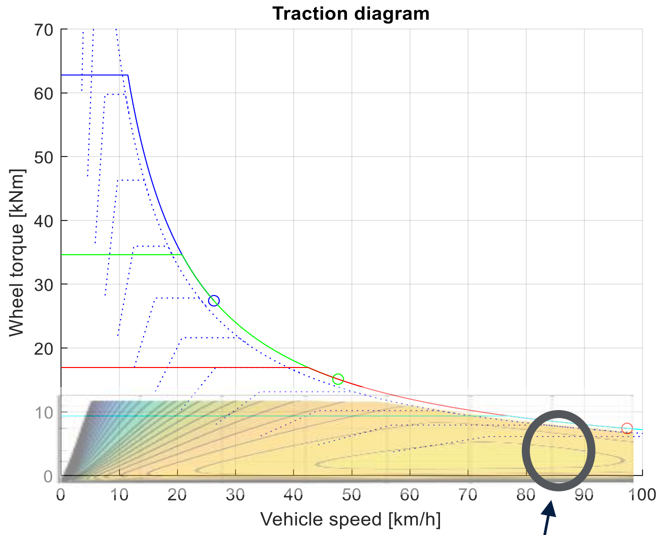
Between 80–90 km/h most of the energy consumed in a LH.

With a more moderate sized motor combined with several gear steps a more efficient drivetrain is created.

Motor is efficient here



But the work is done here



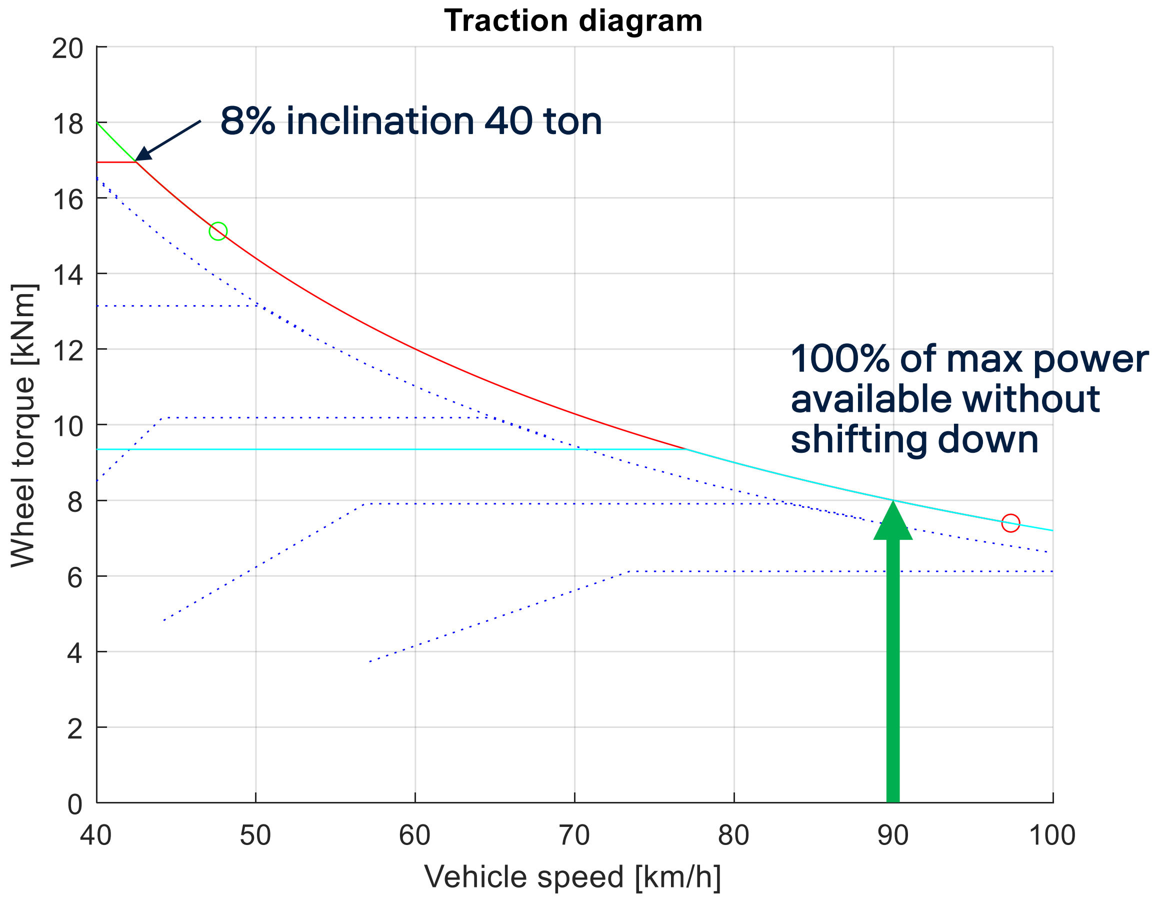
Best efficiency where it is needed

How to compare EV vs ICE

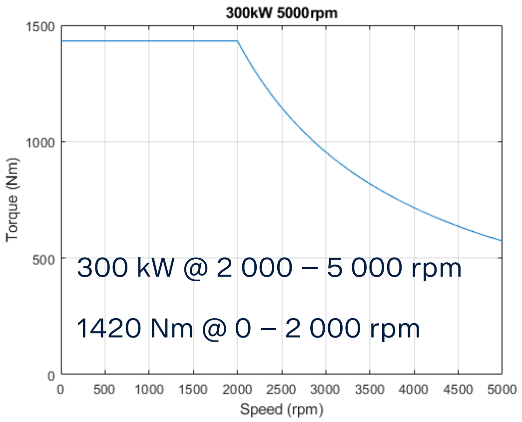
EM C1-4 400kW 4sp vs DC13 174 500hp

Always 100% power available 'under the pedal' without the need for shifting down. Efficient, powerful and yet a very relaxed experience.

Since the gears are overlapping, with look ahead logic and carefully selected gear ratios third gear could be selected ahead of a steep incline. By avoiding gear shift during load we can mimic a power shift experience.



EM-torque is just a result of the EM-rpm

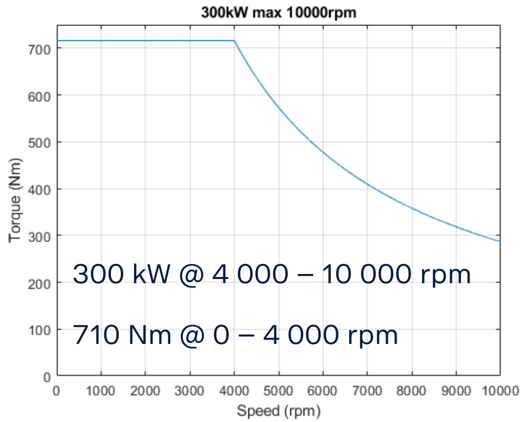


Total ratios

G1=40:1

G2=20:1

G3=10:1

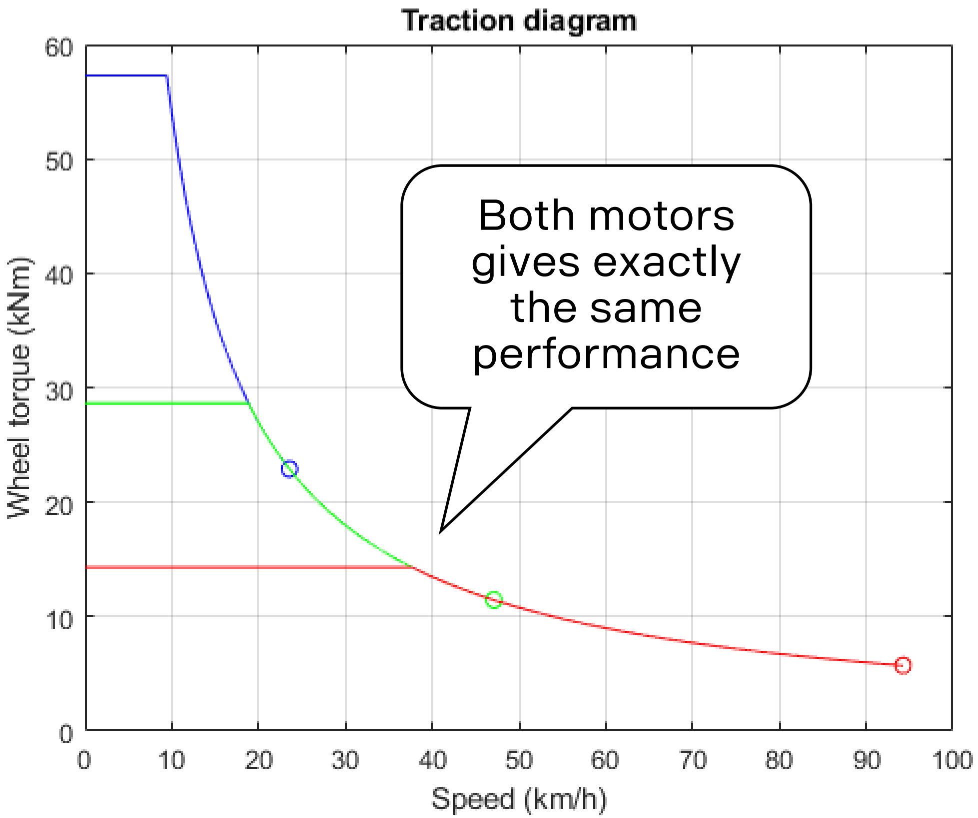


Total ratios

G1=80:1

G2=40:1

G3=20:1



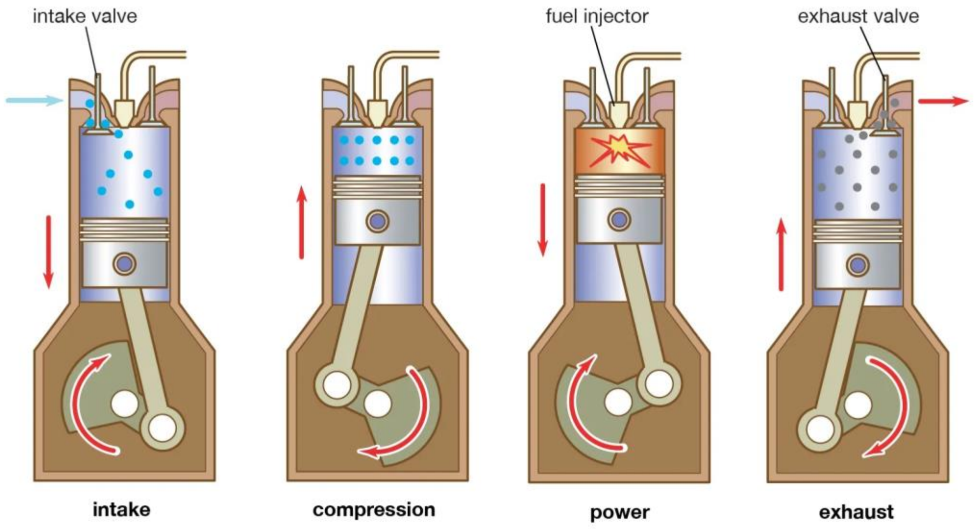
Speed range of the combustion engine

In an ICE the time for each stroke is dictated by physics.

Flow physics to fill the cylinder, flame propagation in during combustion and so on are all time related.

This sets the rpm range the motor operates in.

Diesel engines developed to same requirements have very similar speed ranges.

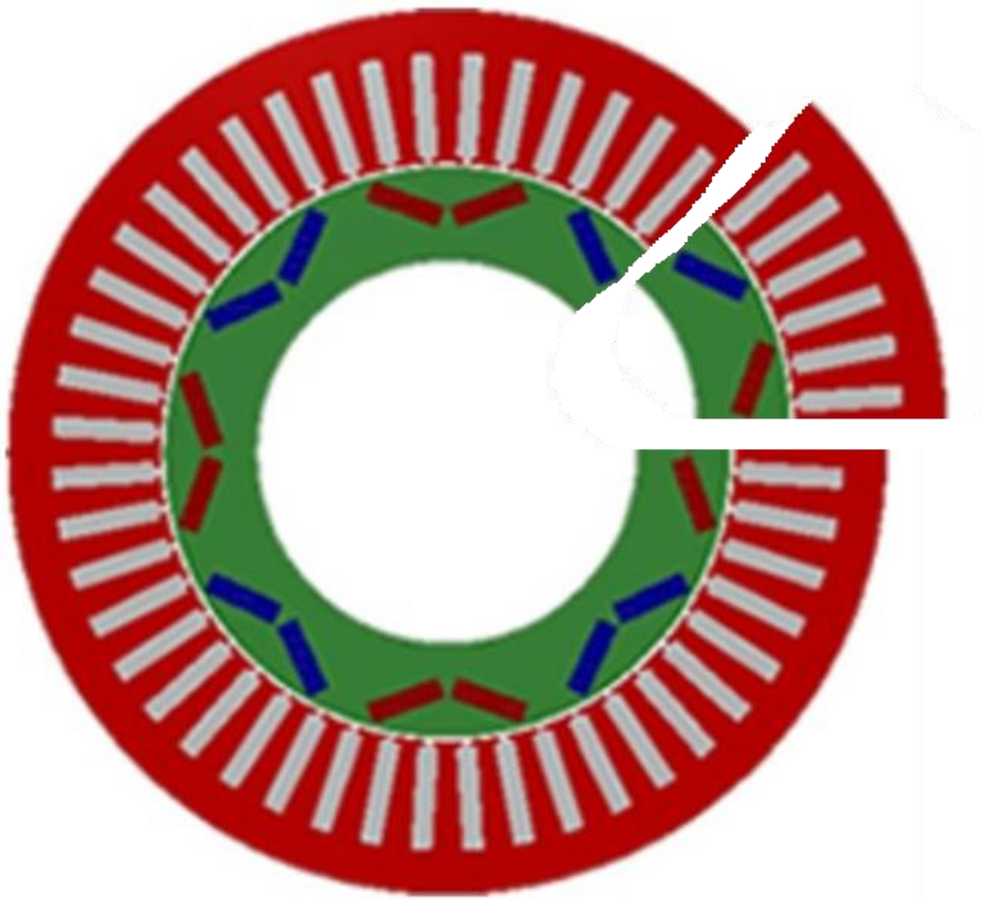


Speed range of the electric motor

The motor consist of several motor segments building up the motor. Looking at a segment it becomes clear that it is the tangential speed in this segment that is the critical parameter.

Depending of the chosen diameter (number of pole pairs) the same tangential speed corresponds to different rpm’s.

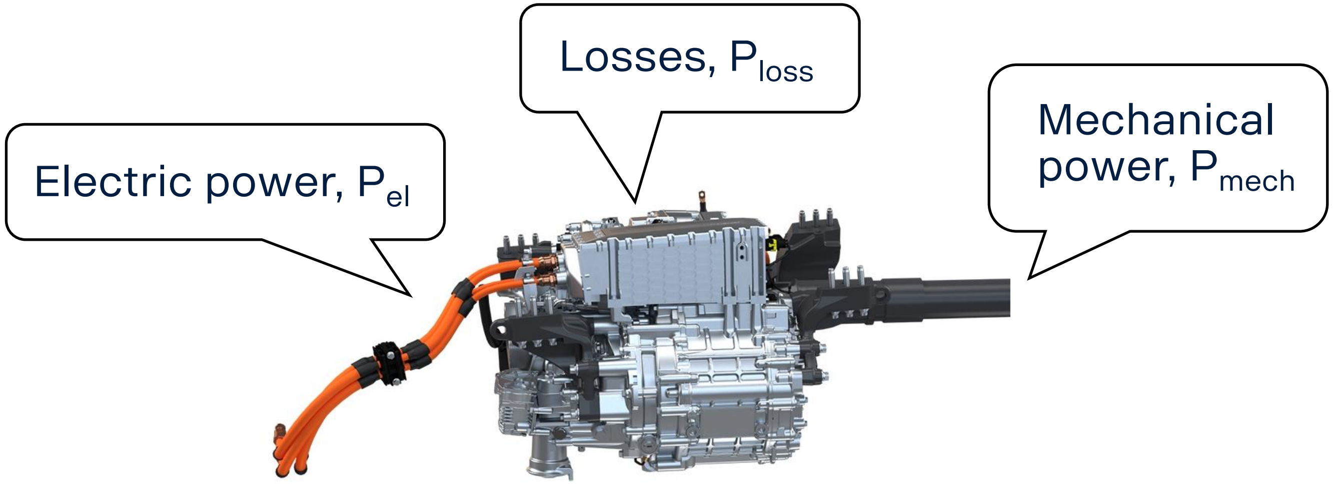
Unlike the ICE, here the RPM range is more free and is the result of various design parameters such as diameter/length ratio, number of pole pairs and so on.



Peak vs continuous
Thermal behaviour of the EM

Losses in the drive unit will drive a temperature change of the unit until the losses (P_{loss}) matches the cooling capacity $(T_{em} - T_{cool}) * h$.

The operating point that reaches this thermal equilibrium at the max allowed operating temperature is the units continuous power rating.



Efficiency defines loss levels:

$$P_{loss} = (1 - \eta) * Pel$$

Law of conservation of energy:

$$P_{loss} = m * c \frac{\partial T_{em}}{\partial t} + (T_{em} - T_{cool}) * h$$

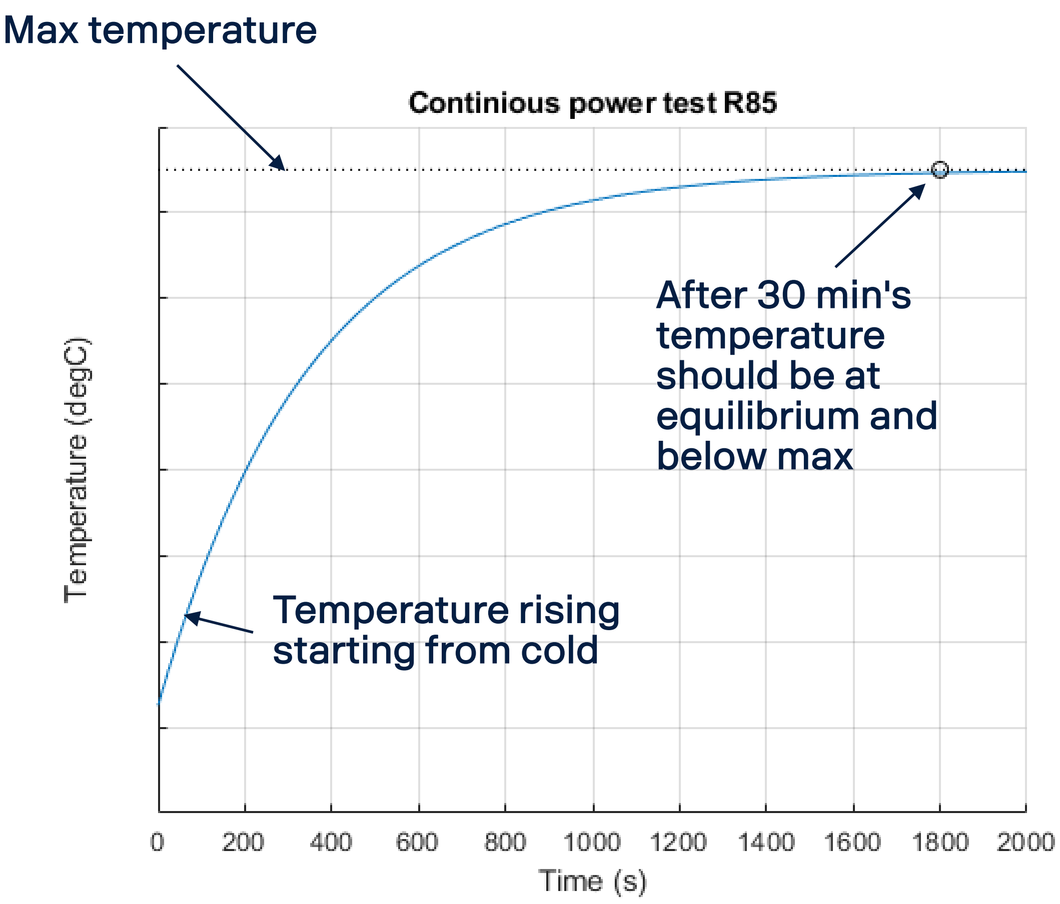
η: Efficiency
m: Lumped mass
c: Specific heat coeff
T_{em}: Temperature of em
T_{cool}: Temperature of coolant
h: Heat transfer coefficient

Continuous power

The definition of P_{cont} in the certification test is the power level that reaches the max allowed temperature in 30 minutes.

The 30 minutes is a good representation of the thermal inertia in typical propulsion motors.

With this knowledge we can look at what happens when we run at power levels higher than P_{cont}.



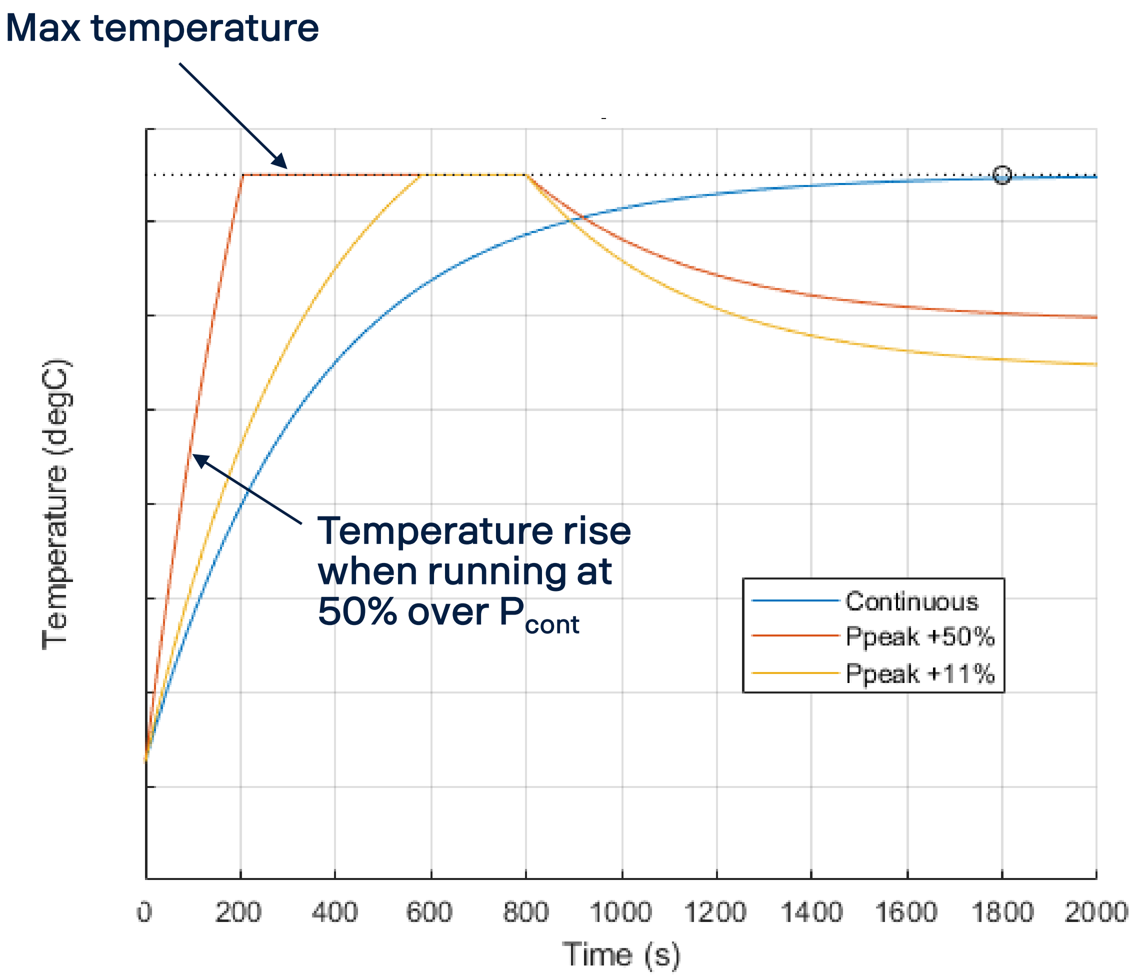
Peak power

The rate of temperature rise is set by the peak/cont ratio.

With a peak 50% higher than continuous max temperature and a deration to the continuous power is reached within 3 min's starting from cold.

The rate of recovery is defined by the continuous power level.

In heavy duty applications peak power being more than 25% higher than continuous is promising a lot more than they reliably can deliver in demanding applications.



Peak vs continuous in practice

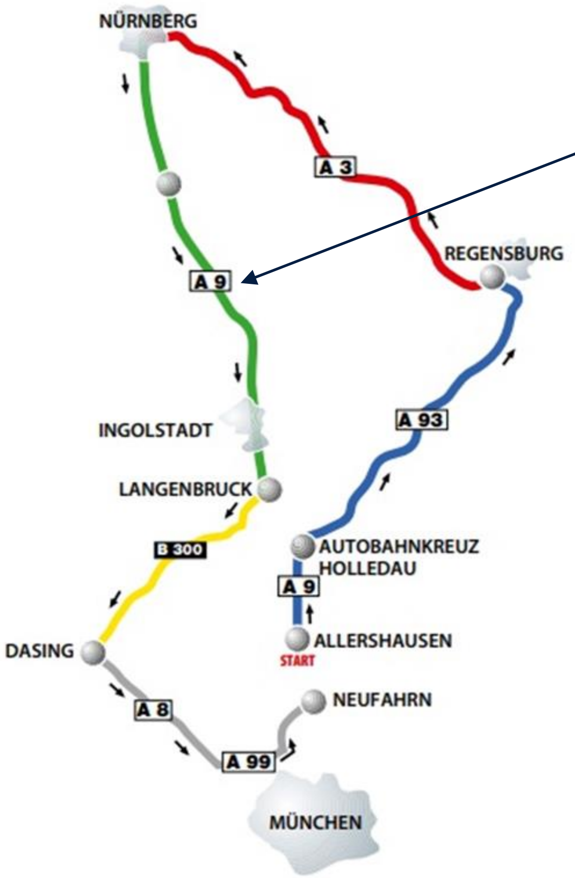
A well known test route in germany contains a hill climb called the Kindinger berg. This is preceeded by some rather hilly parts so the drive train can be expected to be at an elevated temperature.

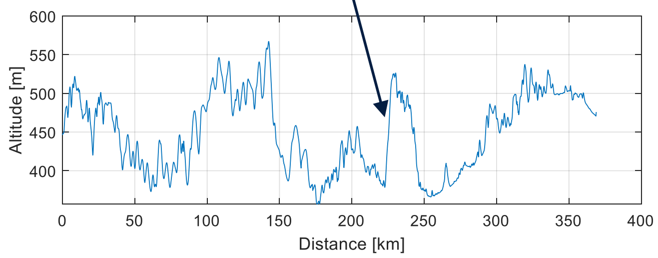
Tests shows that the 500 kW Scania outruns the 600 kW MB with some 13–14 km/h in that hill.

The MB seemed to approach its 400 kW continuous rating whilst the Scania didn't derate at all.

When it really matters, continuous power defines the performance!

Kindinger berg climb





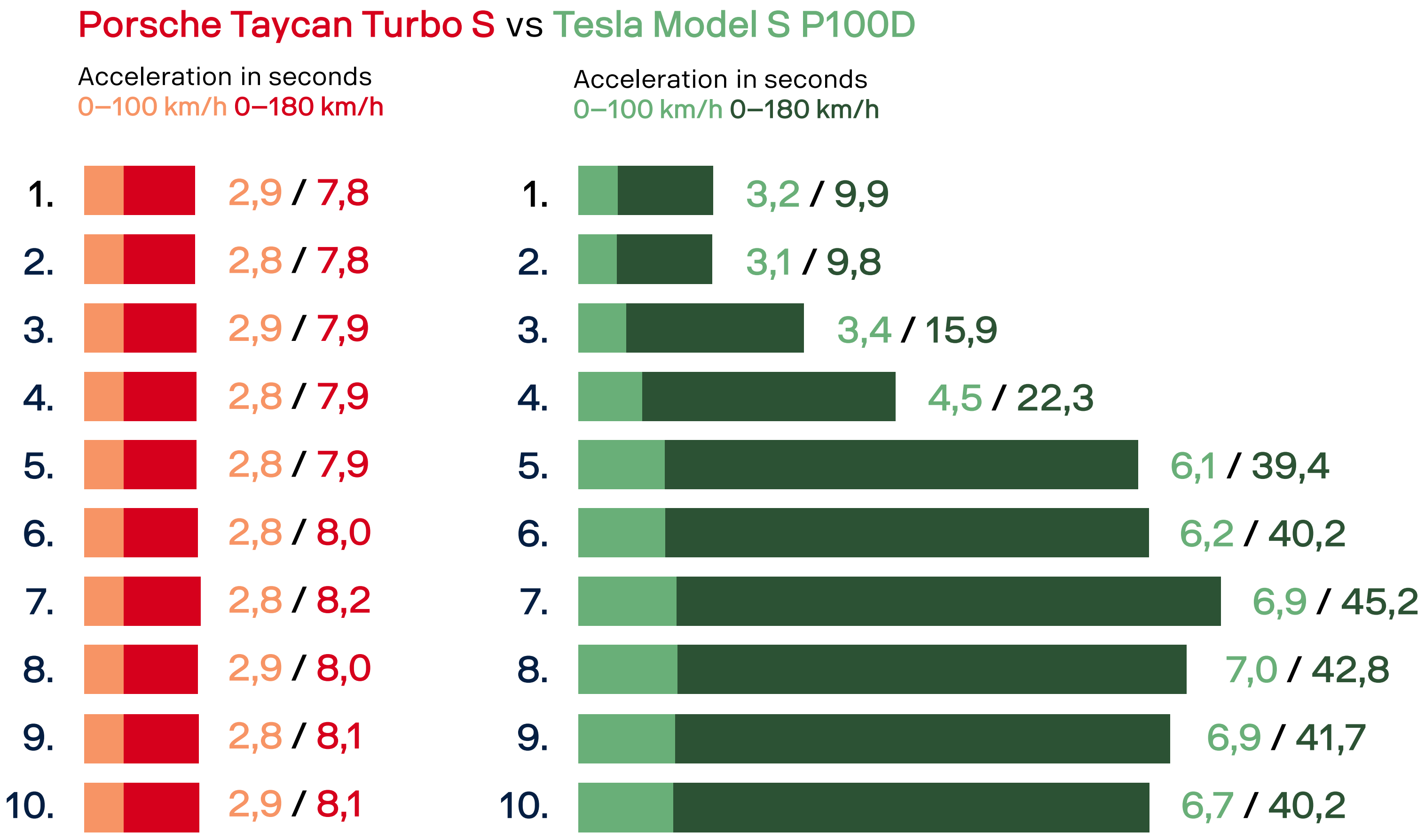
Peak vs continuous in practice

The Porsche maintains its performance independent of how hard it is used.

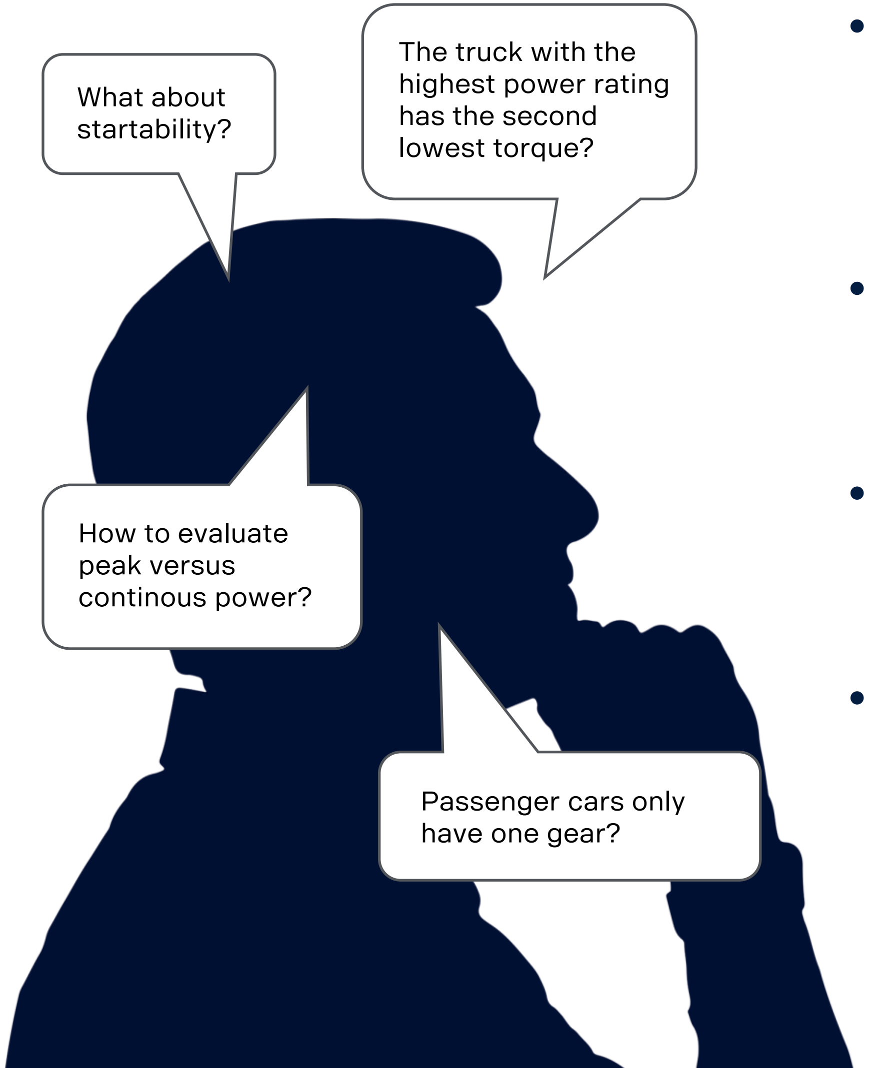
Does this mean that the Tesla is a bad car? Not necessarily. 'Adult driving' with the occasional overtake is a perfect fit.

Understandning of the intended use case and the customer needs is vital.

In demanding applications the continuous performance dictates the characteristics of the vehicle.



Some conclusions



- Starting in hills requires lots of wheel torque. Maximum wheel torque and how long it is available, if not continuous, is of great interest. Selldom seen in data sheets.
- Electric motor torque number does not affect the drivability in any way. It is just a result of the chosen speed range of the electric motor.
- Power ratings where peak power is high (> +25%) relative to the continuous is really promising more than they can reliably deliver in demanding applications.
- To meet the performance requirements over the entire speed range multiple gears are needed to get an efficient drivetrain.