Modeling of diverse mechanical and electrical losses in vehicles

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General view

Rolling losses get more important than drag losses around cities with low speed and traffic jams

The weight of cars did increase a lot in the last 50 years, but the tendency is down again.

The auxiliaries did increase also but LEDs, improved fans, could reverse the tendency.

Introduction

P_{tot} = rolling loss+ drag loss + altitude increase + auxiliaries

Technical:
Altitude and kinetic energy can be partly recovered in EV and HEV
Higher efficiencies from plug to wheel
Better electric motors, transistors: better Si , SiC, GaN : III-V semiconductors
Conventional ICE: downsizing and phase shift in valve control.
$\Rightarrow$ **mechanical losses get important for possible improvements in ICE-V and BE-V**

ICE car driver:
“Liter/100km”
1000 km range
= average in altitude, wind
Many times A-B and B-A

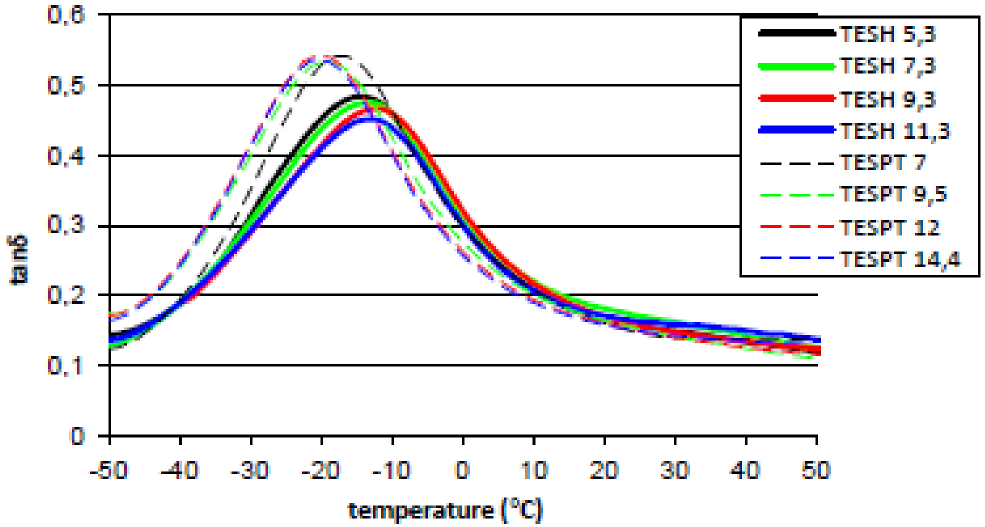
BEV driver:
From “A to B”
“range anxiety”?
Altitude, wind
= more important

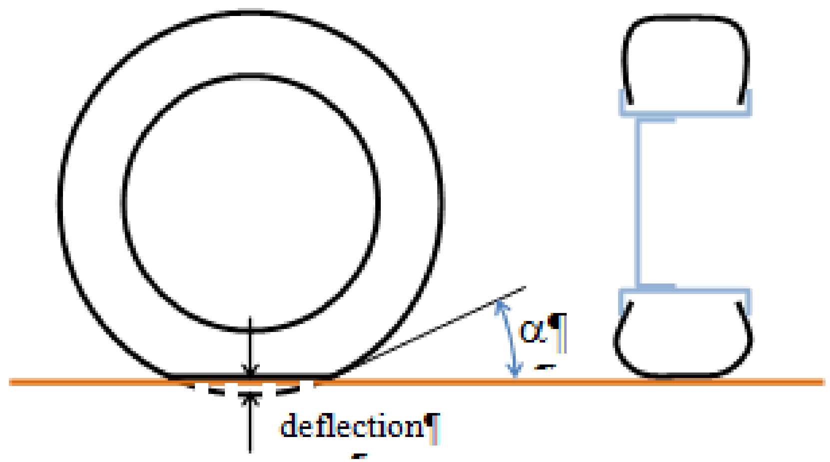
Improvements?
Conventional – BEV?

Global:
CO2, resources

Rolling losses

$$F_R = g\,M\,C_R$$





Side and thread has less losses at high pressure
Thread blocks have more losses at high pressure, but less mass in the blocks
More losses in a new tire as blocs get more peak deformation

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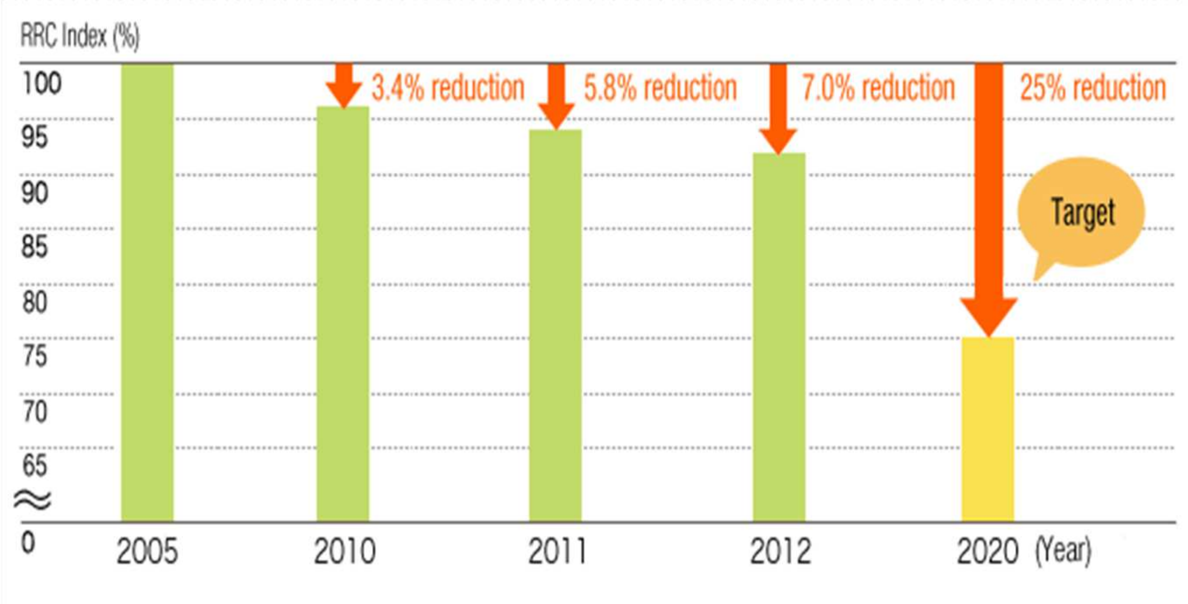
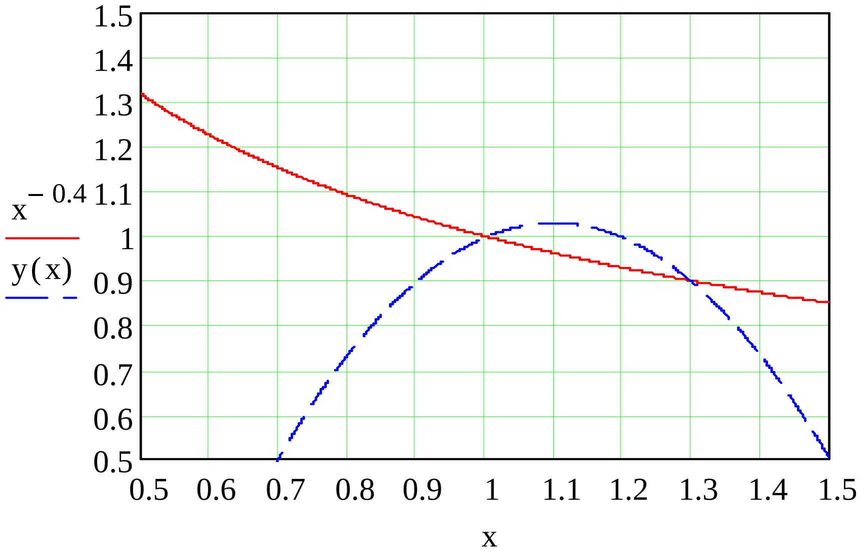
Rolling losses

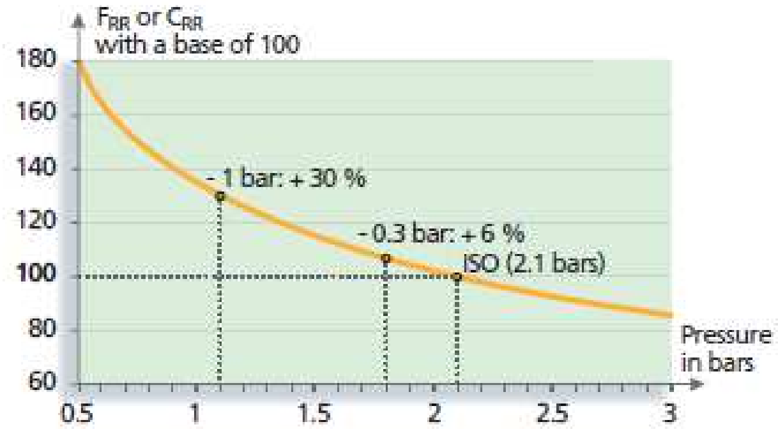
Possible evolution of rolling resistance



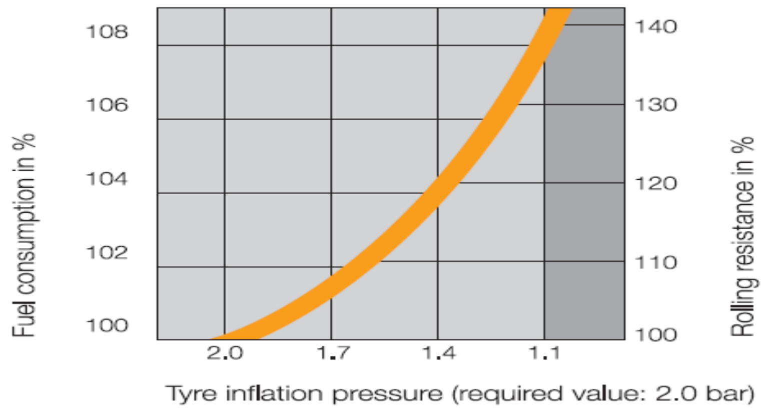
Continental [14]

Rolling losses





Michelin,[10]



Continental [14]

Rolling resistance: red
Lifetime: dashed blue
Depending on relative tire pressure

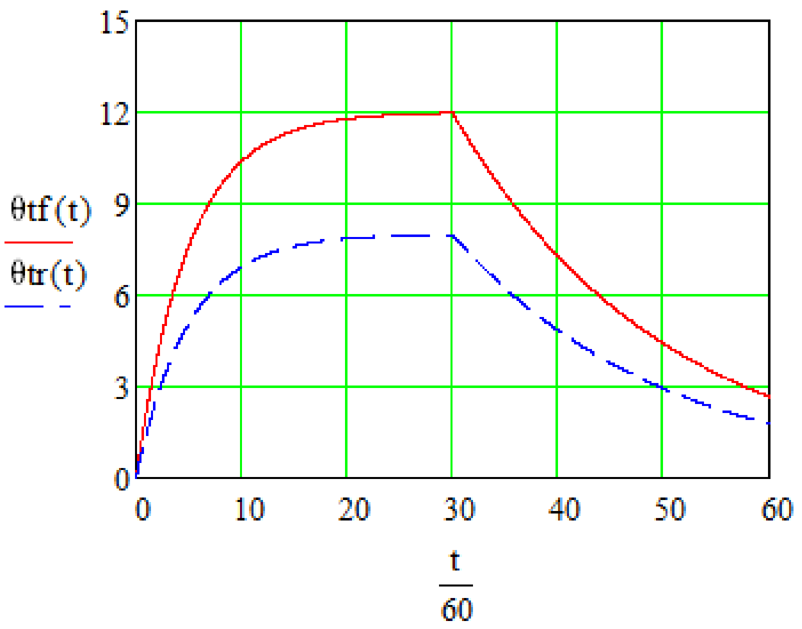
$$F_R = g\,M\,C_{Rref}\left(\frac{p}{p_{ref}}\right)^{-\alpha} \qquad y(x) = 1.033 - 3.3\left(\frac{p}{p_{ref}} - 1.1\right)^2$$

Rolling losses

Thermal capacity of tire: 11.8 kJ/K

Cth = Wr cpr +Wst cpfe

Typical thermal resistance
While driving: 0.025K/W.
Standstill: 0.113 K/W
Time constant = Capacity * resistance



Typical tire temperature rise in [K] for:
- front tire θtf (red)
- rear tire θtr (blue, dashed)

For a conventional car (Punto Evo)
30 minute driving
(5 and 20 minute time constants)

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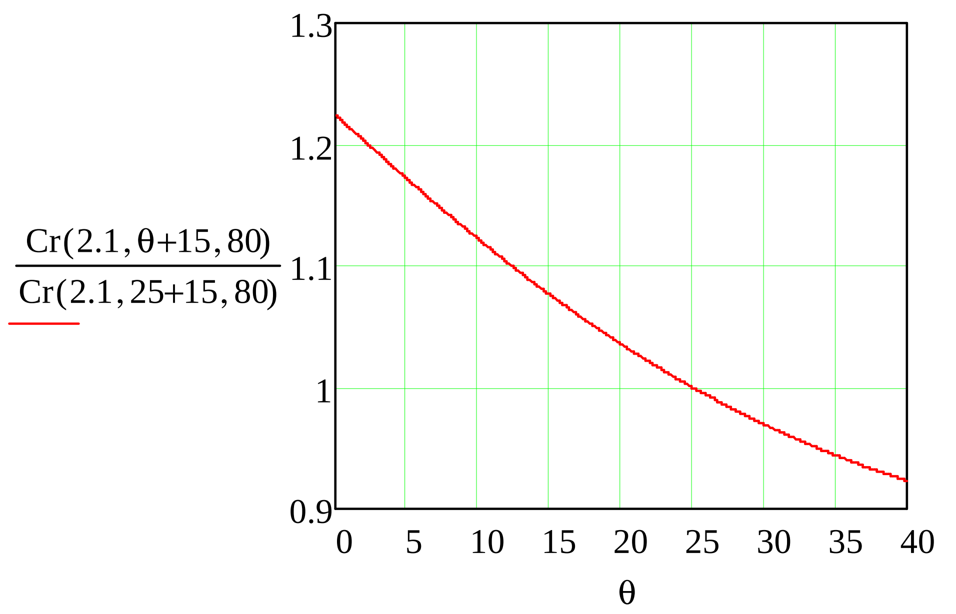
Rolling losses

$$C_R(p,\theta,c) = 0.85\left(\frac{\left(\frac{p}{p_{ref}}\right)^{-0.4}\left(\frac{Z}{Z_{ref}}\right)^{-0.15}}{1+0.35\tanh\left(\frac{\theta-25}{40}\right)} + \left(\frac{c}{500}\right)^2\right)$$

"Collected tire equation":

- *p*: Pressure
- *Z*: Load
- θ: tire temperature
- c: speed [km/h]



Effect of ambient temperature
On rolling coefficient
At 15K rise compared to ambient

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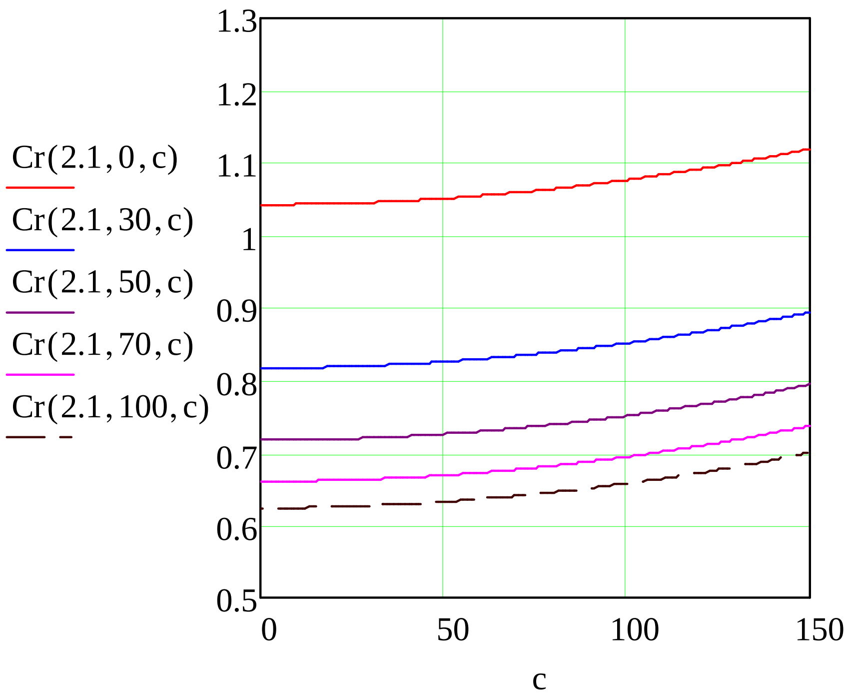
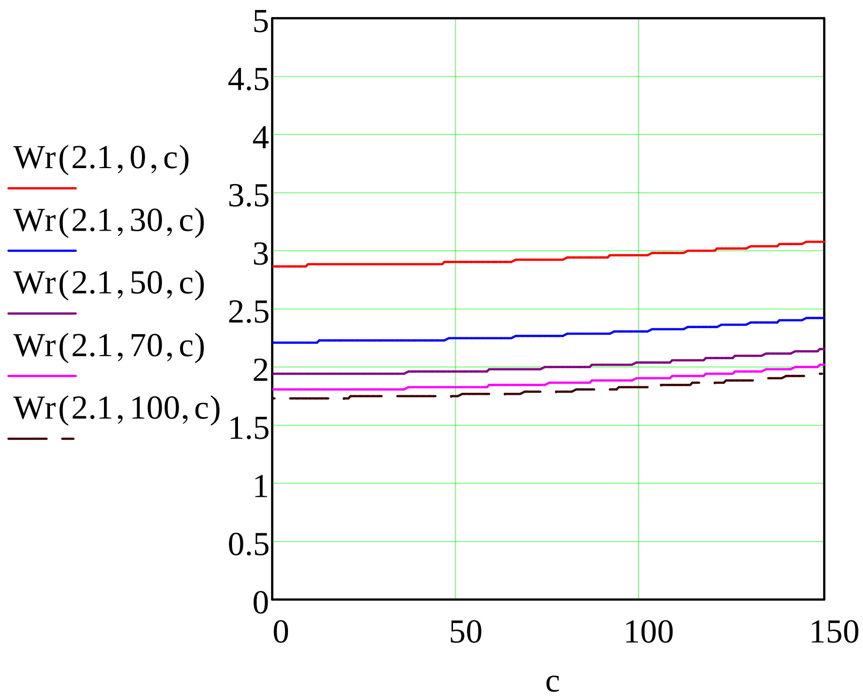
Rolling losses



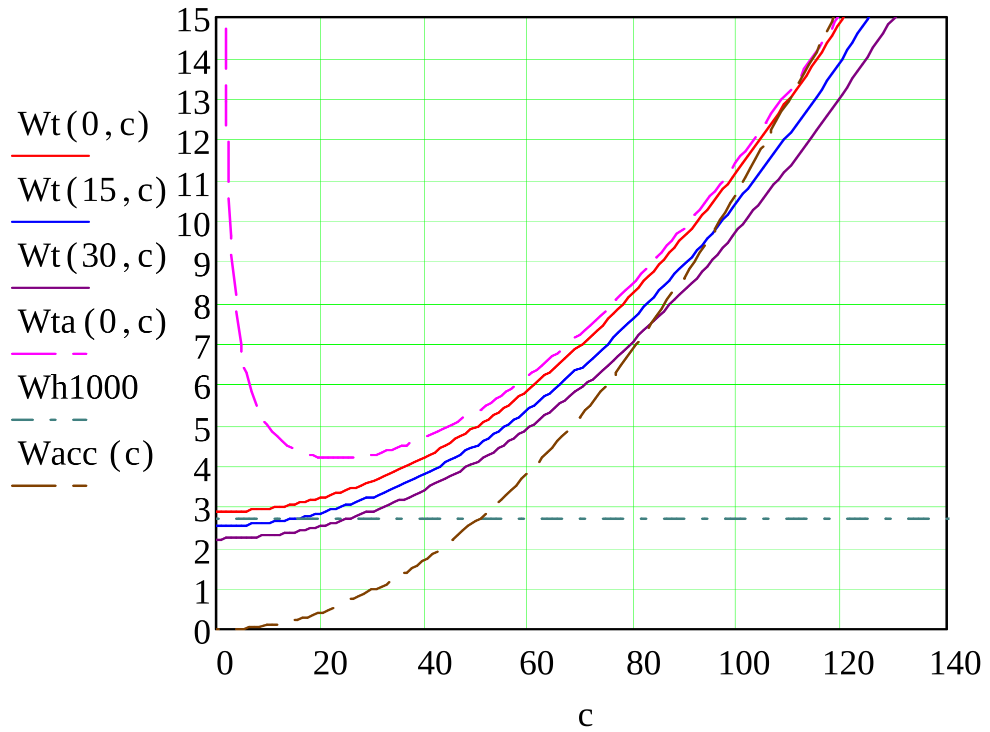


Effect of tire temperature and speed:

Left: rolling coefficient [%] Right: consumption [kWh/100km]

$$C_R(p,\theta,c) = 0.85\left(\frac{\left(\frac{p}{p_{ref}}\right)^{-0.4}\left(\frac{Z}{Z_{ref}}\right)^{-0.15}}{1+0.35\tanh\left(\frac{\theta-25}{40}\right)}+\left(\frac{c}{500}\right)^2\right)$$

Total losses



Overview

Wt: Rolling + acceleration, at 0, 15, 30 °C, (tire and air)

Wta: total =Rolling+ drag + auxiliaries (200W) at 0°C

Wh: 1000m climbing in 100km

Wacc: accelerating each km without recovery.

Altitude & Acceleration

$Wa = M\,\Delta h \times g$

$Pacc(c) = M\,(c/3.6)\,a$

is 9.81 MJ/1000m/ton
= 2.725 kWh/1000m/ton

Is a Lower weight possible?
Yes 50 years ago, even 100years ago…
Or old timer conversions?
Extreme designs can get down to 30kg

- *Citroën Mehari, 570kg [17]*
- *Fiat 500, 1957, 499kg*
- *Renault 4 1961 540kg*
- *Volkswagen beetle: 750kg [18]*
- *New beetle 1274–1505 kg*
- *Apal Buggy converted to electric (beetle chassis): 700 kg*

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Weight

Weight

100 years ago Smith Flyer USA
1914-1920
About 100 kg
Briggs and Stratton
+ afterwards electric

WAW: human powered 30kg
E-WAW: human+electric assistance 250W, 35kg
www.fietser.be

Local future BEV
Elbev type: < 100kg, 80km/h
Will be changed to ULBEC
With improved design

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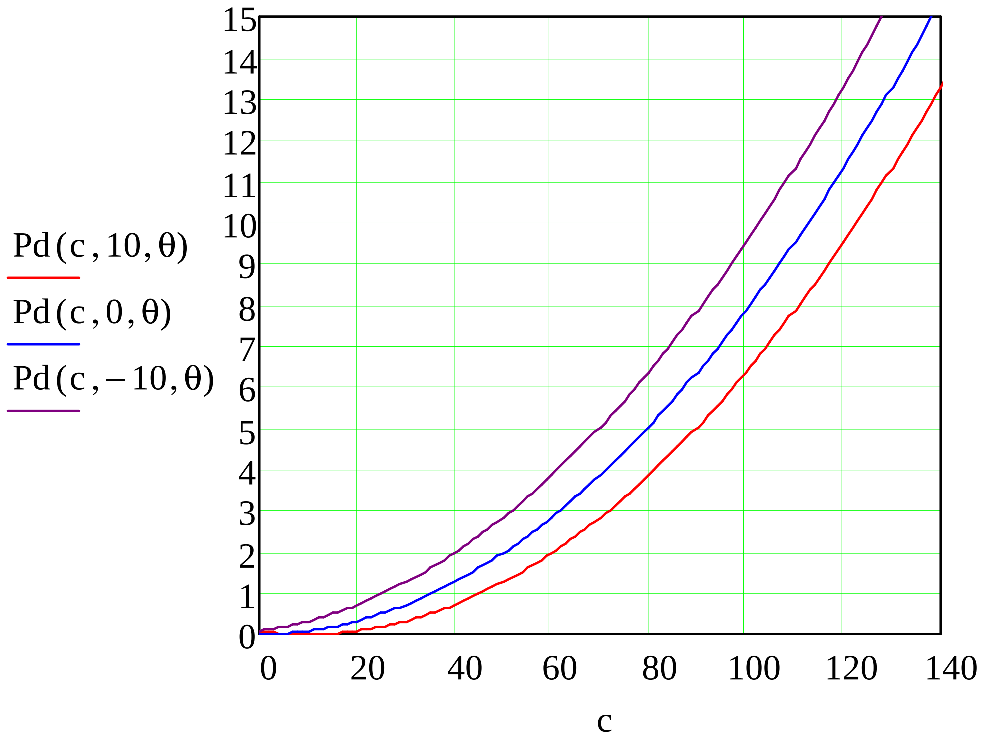
Drag & Wind

Drag including local wind

$$Fd(c,c_{wx}) = \frac{1}{2} A\, C_d\ \rho_o \frac{273}{\theta+273}\left(\frac{c-c_{wx}}{3.6}\right)^2 \frac{10^5}{3.6\times10^6}$$

Drag
- Without wind
- +10km/h
- -10km/h

Look at 60km/h,
Still a strong influence!



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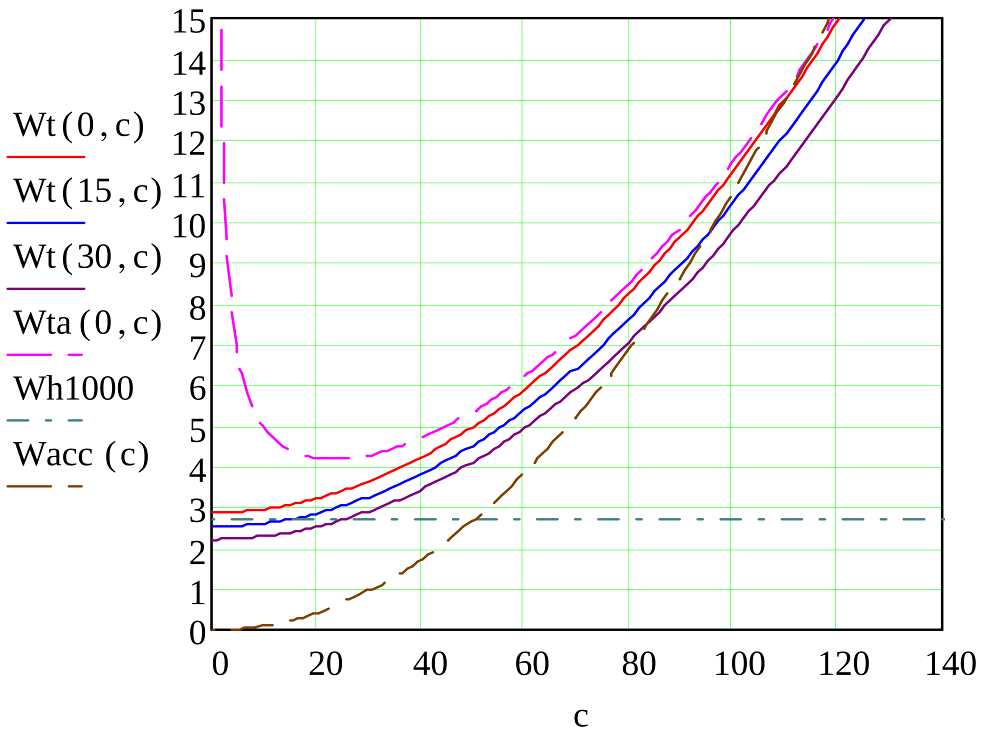
Total: *Rolling, Drag, Altitude, Acceleration, Auxiliaries*

Total losses: shown curves

- ✓ 0°C, 15°C, 30°C tire - air
- ✓ 0°C + 200W aux.
- ✓ Acceleration each km
- ✓ 1000m climbing for 100km

Drag and tire :
temperature effects included



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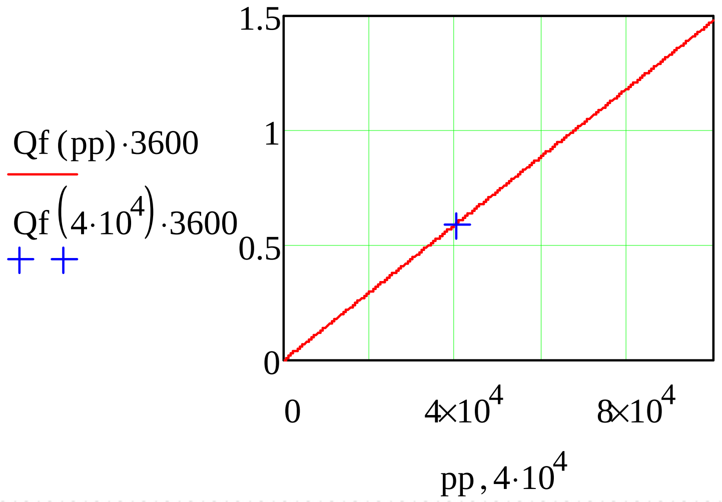
Idling losses Gasoline & Diesel engines

Idling for a 4stroke gasoline
= throttle valve loss
gasoline engine at 800rpm
≈0.6 Liter/hour/1000cc

Idling for a pure diesel engine

- 0.4-0.5 Liter/hour/1000cc
- Mainly friction loss

But
1 liter/h start stop + good driver
2 liter/h normal car + normal driver
3 liter/hour for SUV



Gasoline consumption at 800rpm/1000cc
As function of pressure after throttle
- Pressure in [Pa]
- Flow in liter/hour

Solution for idling losses?

- Start-stop
- Downsizing
- Series hybrid?

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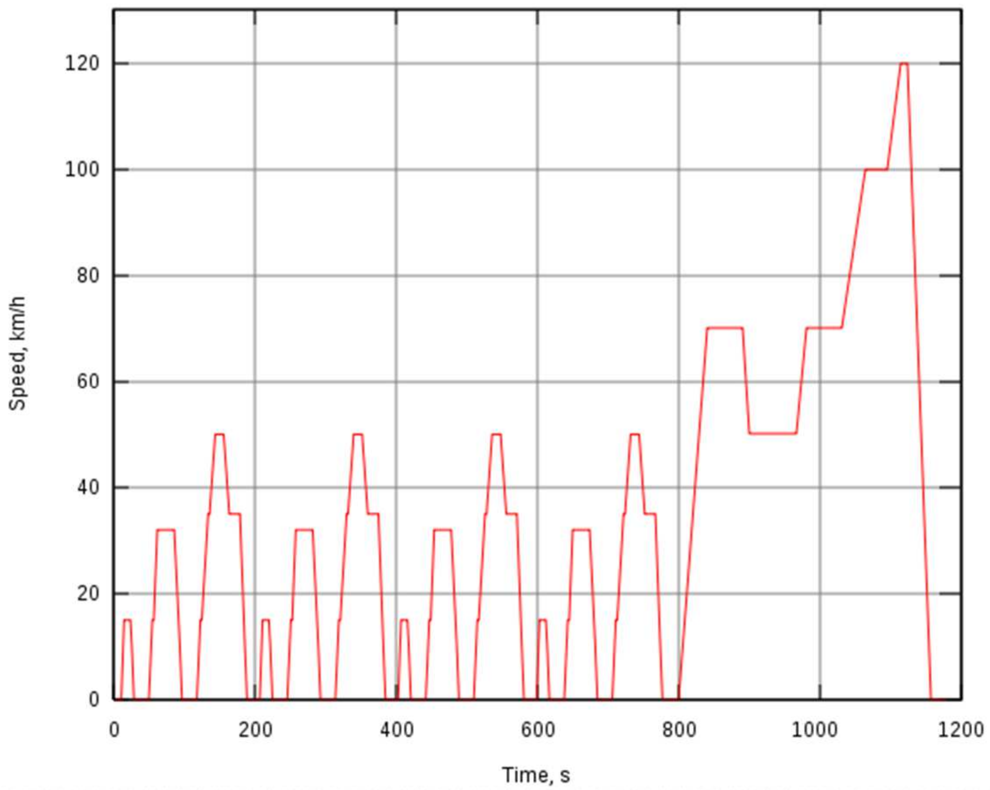
Standard test NEDC

Standard tests?

NEDC
- Different from reality: w**hy?**
- 17 reasons are identified
- Corrected for error in dashboard meter
- Fiat Punto EVO
- Listed at 3.5 l/100km
- 1200kg.



NEDC speed profile
New European Driving Cycle

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Tricks to get at NEDC

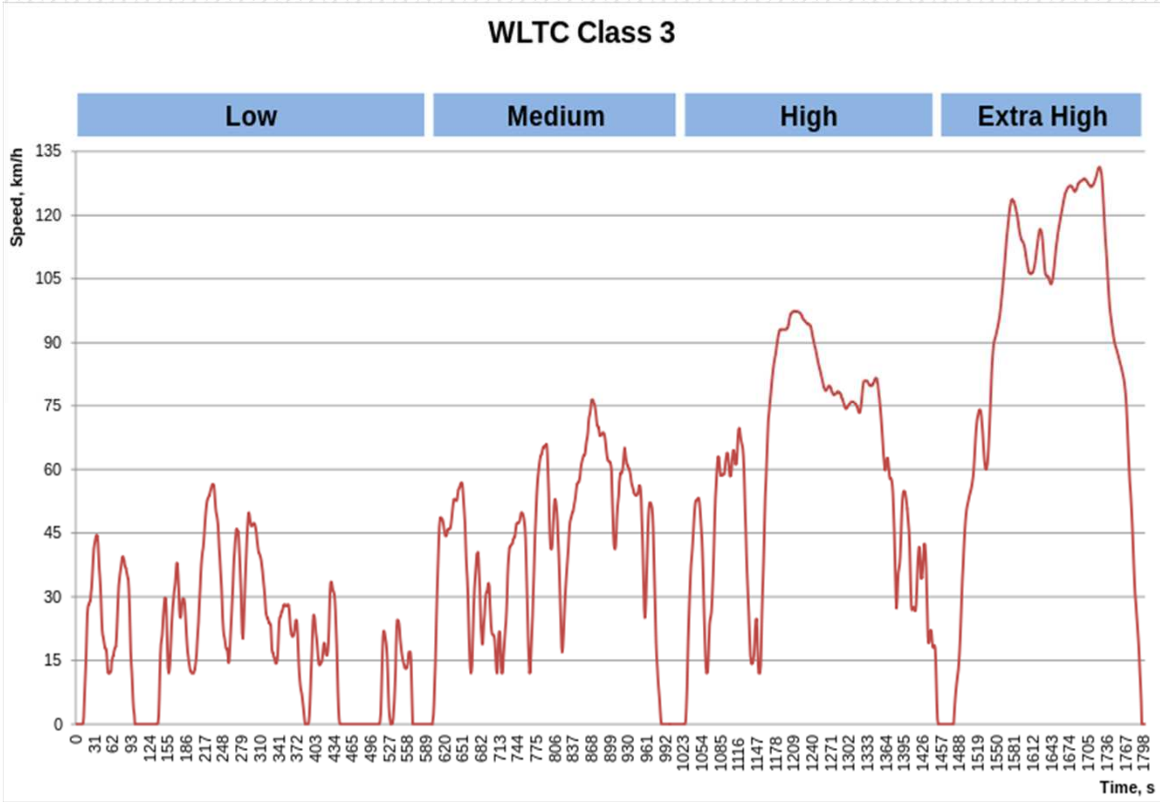
17 reasons are identified => listed NEDC of 3.5 l/100km is reached

1. Ambient temperature **above 20°C** (tire, aerodynamic friction, gear oil).
2. Tires inflated at **260 kPa** compared to 220 kPa normal (<350kPa = tire specification)
3. **No lights** on, no high fan (= reduced auxiliaries).
4. **Air conditioning off**.
5. **No traffic jam**, about 30 stops/100km.
6. Buying a 2-door model, as a 4-door model weighs more but is **listed with the same consumption** in the NEDC standard.
7. **Not below 15 000 km**, this is avoiding the run-in period.
8. **Not** with rather **new tires**.
9. Outside city, each 100km run the diesel at idle for 3 seconds at **5000 rpm to clean** the engine
10. **Removing the spare wheel** and replace it with a repair kit.
11. **Oil level** between 40 and 60% between minimum and maximum (in the maintenance they put often too much oil)
12. **Driving-style** with some freewheeling, (but still motor on), rather low rpm, motor braking at about 2000rpm is used to charge the accumulator
13. **Slow deceleration** towards traffic lights when traffic permits.
14. Typical speeds **between 40 and 95 km/h**,
15. Sometimes at 50m (not closer for safety) **behind a truck** at highway.
16. **Covering the radiator** for 70% (improving the drag and to limit the cooling of the gear) it can be done below 25°C
17. Some **0.3% acetone** in the diesel (improves mileage at low torque)

Standard test WLTC

Standard tests?

WLTC
- About 1.5m/s²
- **(<-> 0.5m/s² for NEDC)**
- But no sustained speeds of $
- 5-10km/h as in today traffic jams: also this test: **will be too optimistic….**
- Above 20°C (but a variant in Europe with including also a test at -7°C = OK



WLTP speed profile
World harmonized Light Vehicles Test Procedures / Cycles

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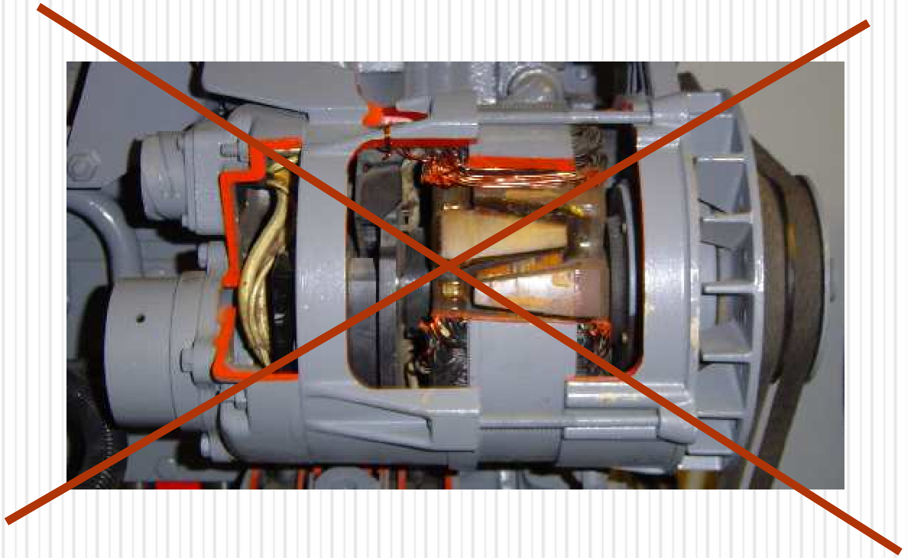
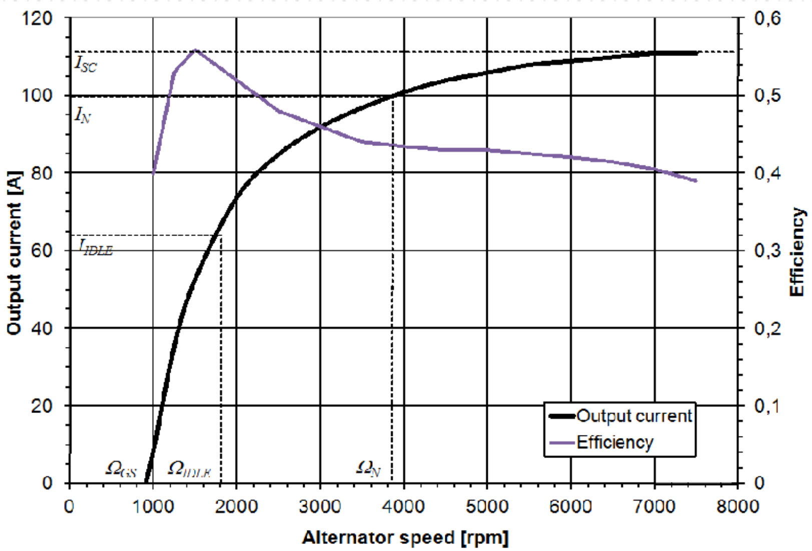
Improvements

Improvements in electric in traditional ICE cars:

- Lower weight, downsizing, hybrid
- Use a better alternative for the Lundell alternator
- Performance in traffic jam?
- Led lamps instead of filament
- More efficient fans
- White color, reduce sunlight penetration and insulation to reduce airco needs





[Power Electronic Solutions to Improve the Performance of Lundell Automotive Alternators]

Improvements

Improvements in Electric cars?

- **Lower weight** down to <100kg/person
- Losses of drive <20% of roll and drag
- Performance in traffic jam?
- Led lamps instead of filament lamps.
- More efficient fans
- White color and insulation to reduce airco needs if it is really needed?
- Fan on PV panel to ventilate when parked in the sun

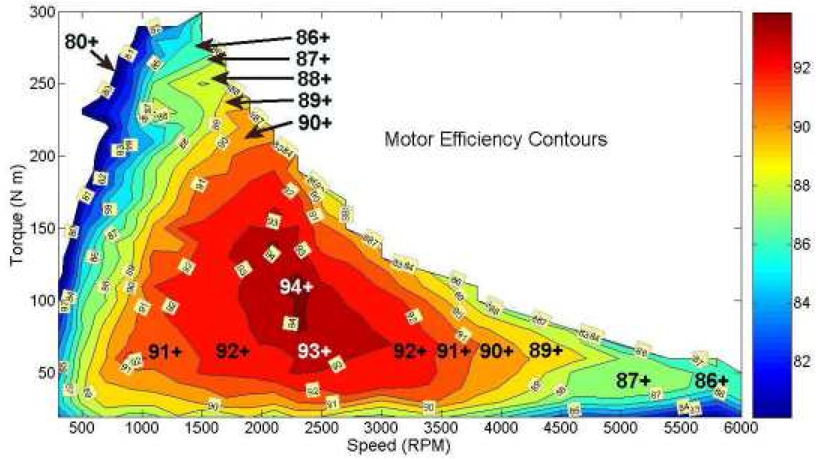
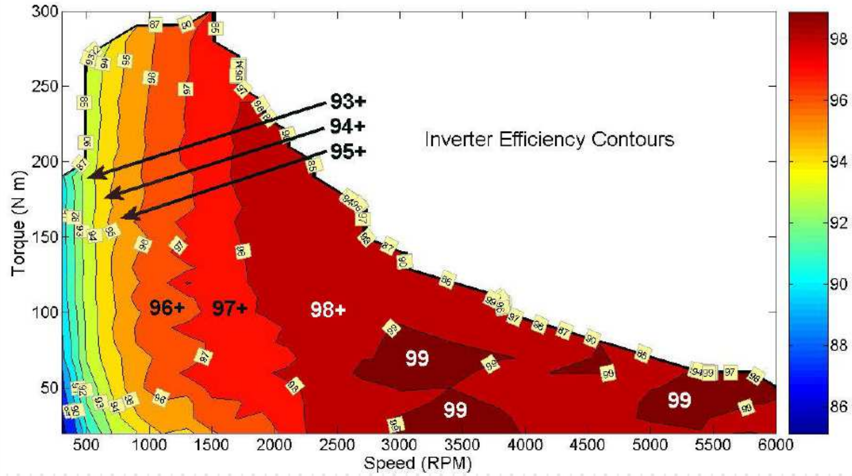


Fig. 3.18. 2004 Prius motor efficiency contour map.



Electric motor efficiency is achieved, for example the drive of Prius (see right) is good but:

- Heavy weight 1317kg
- The ICE of the Prius v is still 1000 even 1800cc, too large, some 4.1 liter/100km without emptying battery.

[http://en.wikipedia.org/wiki/Toyota_Prius_v]

Pure ICE and pure electric cars have a lower consumption

http://www.osti.gov/scitech/biblio/890029

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Conclusion

- Reduce weight, for rolling loss
- Reduce weight, for kinetic energy losses
- Reduce weight, for altitude changes (BEV)
- Reduce auxiliaries (LED, better fan)
- Get better electric efficiencies (in BEV and Lundell generator

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