Motor oil, fuel economy and real driving emissions in the era of E-mobility

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stle
Society of Tribologists and Lubrication Engineers

BIZOL Made in Germany

ANS Applied Nano Surfaces

Highlights

- Zero emission hype: CO2 footprint of electric vehicles
- NEDC, WLTP, RDE… What it's all about?
- Low-friction powertrain concept: the characteristics of future ICE
- Resource-conserving motor oil: formulation principles
- Growth of synthetics
- New motor oil categories
- Development and approval challenges

Zero emission hype

Zero emissions won't be possible until a "perpetuum mobile" is invented.

"Perpetual motion, the action of a device that, once set in motion, would continue in motion forever, with no additional energy required to maintain it. Such devices are **impossible** on grounds stated by the first and second laws of thermodynamics." *Source: Encyclopaedia Britannica*

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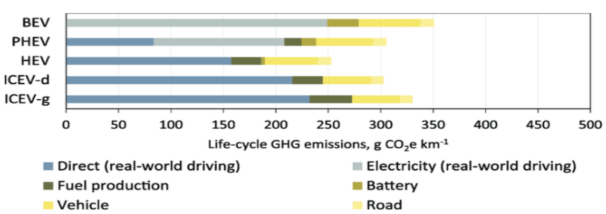
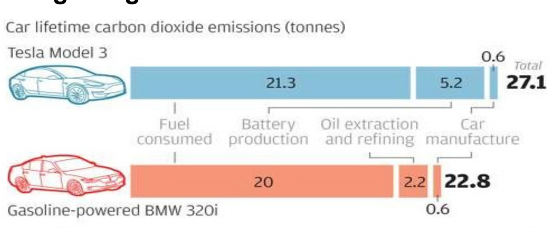
Zero emission? Not quite.

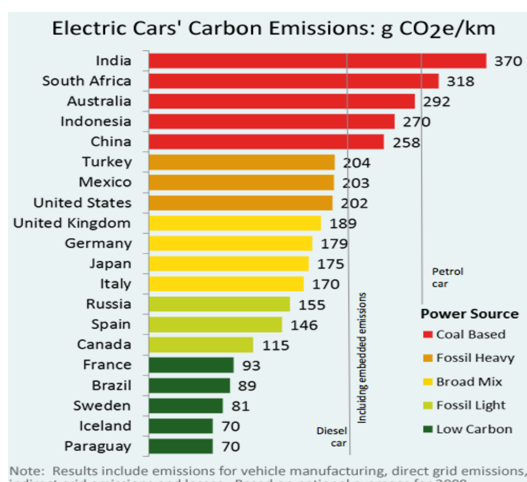
Australia



Ref.: P. Wolfram, T. Wiedmann, Applied Energy 206 (2017) 531-540.

Hong Kong





Source: Euan Mearns, Energy Matters, 2017

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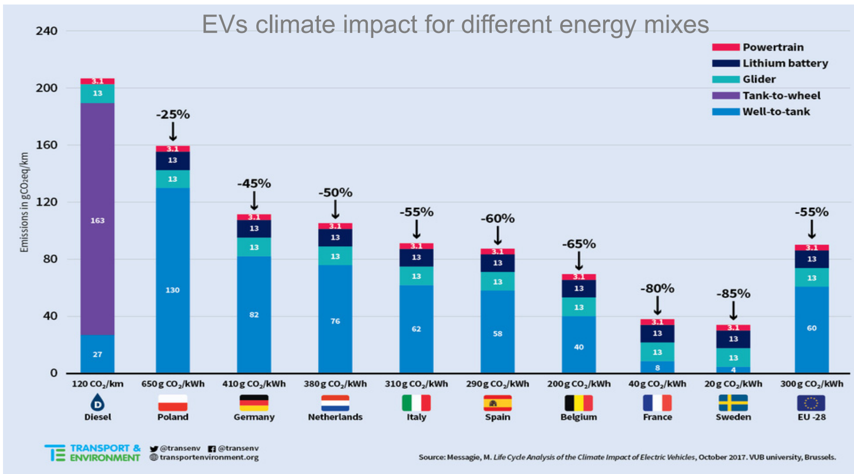
Brussel's view is more optimistic, of course



Results depend on assumptions and LCA depth.
For instance, in Sweden, the annual el production is ca 140 TWh.
The number of cars is ca 4.8 M.
Average battery is 50 kWh, Charged once per week.
If all the cars become BEV, one would need ca 240 GWh per week or 12 TWh per year extra.
Hence, Sweden can afford a "green" BEV fleet.

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A conspiracy theory? Not at all!

Battery manufacturing with current technology consumes 100-180 kWh energy per kWh battery capacity

GHG burden of current battery production is 150-200 kg CO2 / kWh

Source: Mia Romare, Lisbeth Dahllöf, The life cycle energy consumption and greenhouse gas emissions from litium-ion batteries, IVL Swedish Environmental Research Institute, 2017

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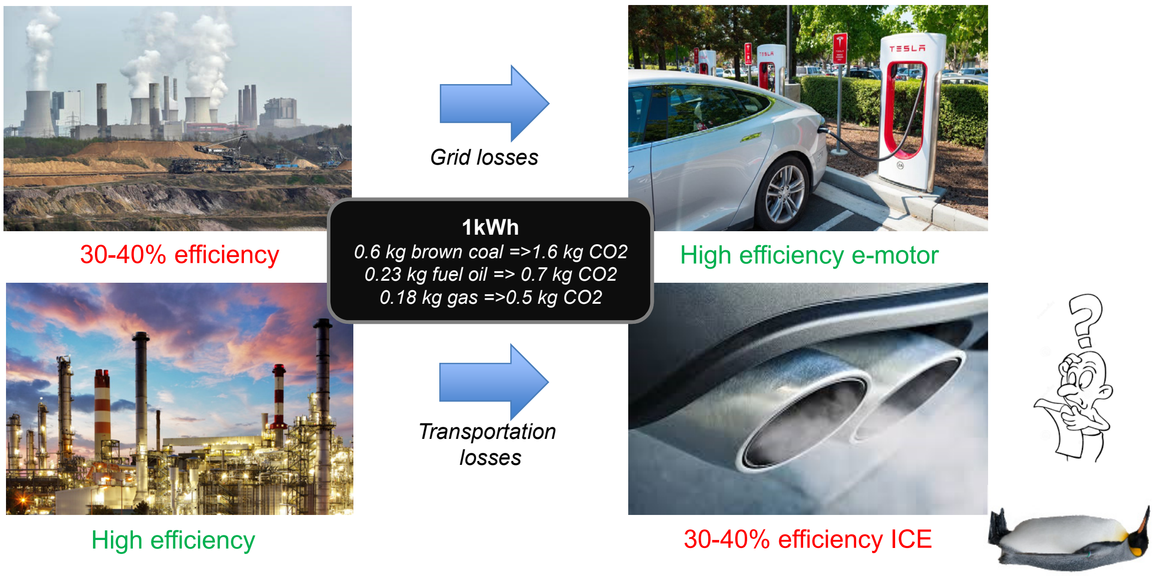
The quest for greener energy mixes



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LCA CO2 emissions data by Ricardo & LowCVP

	Estimated lifecycle emissions (tonnes CO2e)	Proportion of emissions in production	Estimated emissions in production (tonnes CO2e)
Standard gasoline vehicle	24	23%	5.6
Hybrid vehicle	21	31%	6.5
Plug-in hybrid vehicle	19	35%	6.7
Battery electric vehicle	19	46%	8.8

Some 20% reduction is possible

For a typical 2015 vehicle in use for 150,000 km using 10% ethanol blend and 500 g CO2 / kWh grid electricity.

"This work dispels the myth that low carbon vehicles simply displace emissions from the exhaust to other sources. However, it does highlight the need to look at reducing carbon emissions from vehicles throughout their lifecycle."

Source: *Greg Archer, LowCVP*

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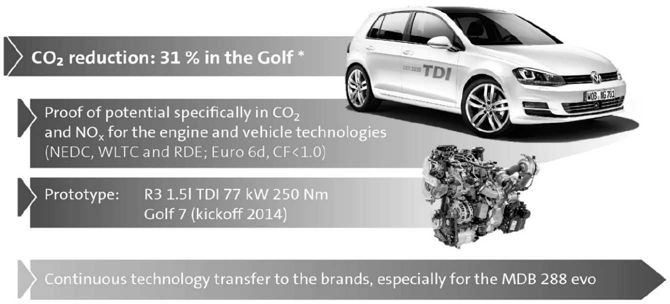
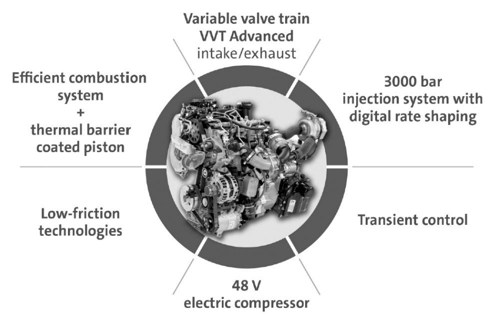
But 20% GHG reduction is also possible by “routine” ICE optimization

and with an immediate effect





* Reference: Golf 7 with EA288 1.6l R4 evaluated under NEDC

Ref: Dr. Aiko Mork, Christian Heimermann, Martin Schüttenhelm, Michael Frambourg, Dr. Michael Henn, Dr. Tobias Lösche-ter Horst, CO2-Lighthouse Diesel Engine from Volkswagen Group Research, 27th Aachen Colloquium Automobile and Engine Technology, Aachen, Germany, October 8-10, 2018.

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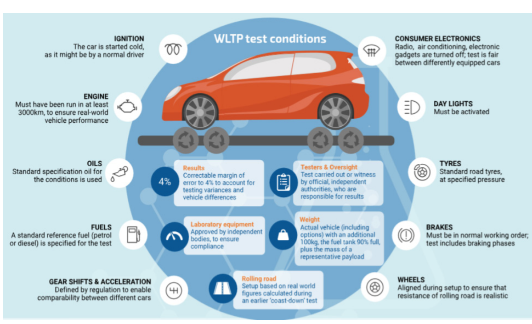
NEDC, WLTP, RDE… What it’s all about?

NEDC, WLTP

- Basis for vehicle CO2 taxation and “formal” compliance with official CO2 emission targets
- Senses the resource-conserving efficiency of lubricant.

RDE

- On-road test to prevent future “dieselgates”.
- Focus on NOx and PM emissions, less affected by lubricants



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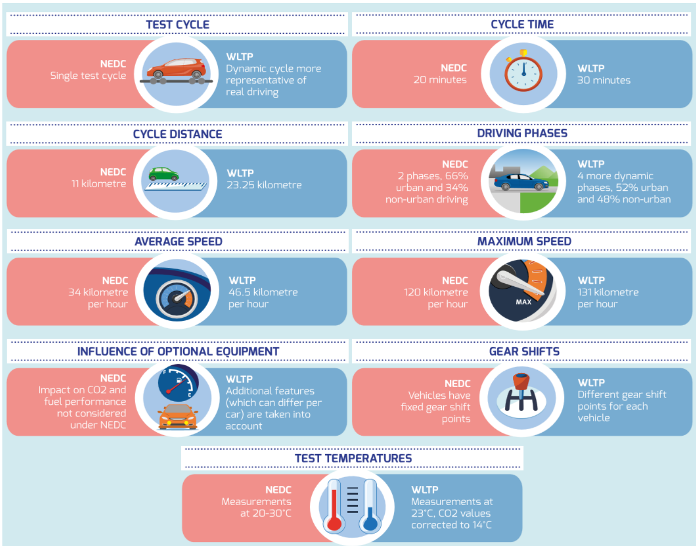
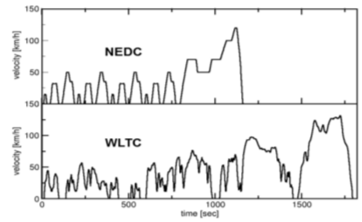
WLTP vs NEDC

Key differences and response to lubricant

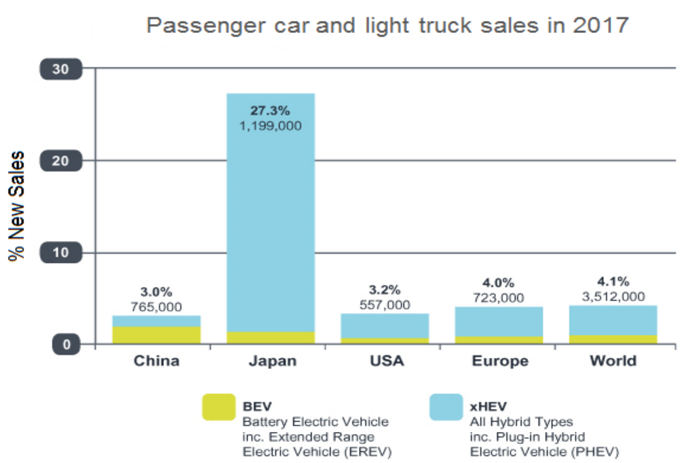




$$CO_{2,WLTP}\left[\frac{g}{km}\right] = CO_{2,NEDC} + 0.05 * \Delta M[kg] + 3$$

- ✓ Oil viscosity has more effect on NEDC;
- ✓ Friction modifiers have more effect on WLTP;
- ✓ Hybrids shine in the tests

Hybrids set to dominate by 2040



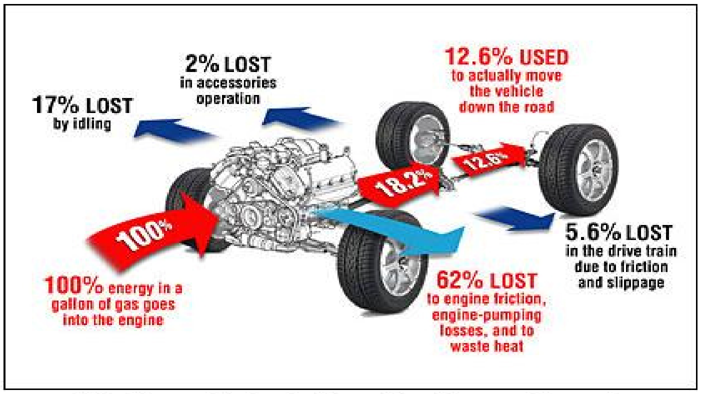
Source: LMC Automotive Global Hybrid & EV Forecast, 2017

Magic behind Porsche Panamera 4 E-Hybrid
460 hp (330 hp V6 + 130 e-motor), 700 Nm

Fuel consumption 2.5 l / 100km, CO2 56 g/km

Mind the embedded CO2 footstep!

Lowering powertrain friction remains actual



This diagram illustrates the paths of energy through a typical gas-powered vehicle in city driving.

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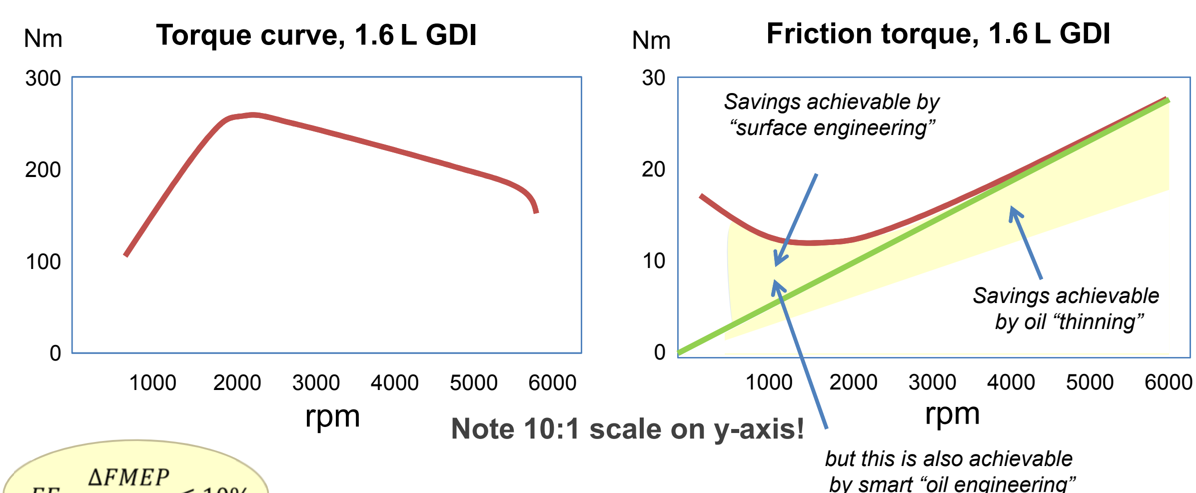
How much can be saved?



$$FE \sim \frac{\Delta FMEP}{IMEP} \leq 10\%$$

B. Zhmud, 2nd Int. Workshop "Superlubricity in the Real Automotive World", Brazil, 2018

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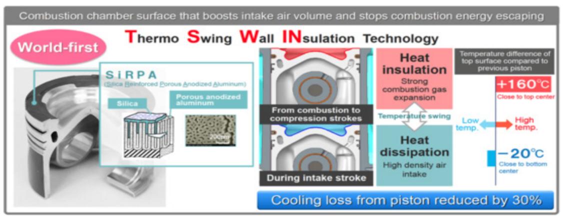
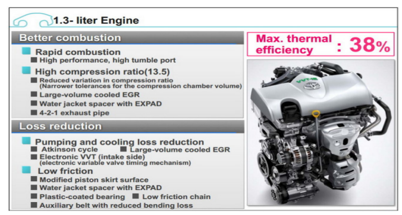
Characteristics of future car's ICE

- ❑ Downsized: 2-4 cylinders, 1-2L displacement
- ❑ Heavily boosted, 150+ hp / L
- ❑ Down-speeded
- ❑ Start-stop
- ❑ Advanced emission control equipment (TWC, DOC, DPF, SCR, etc.)

Other possible techniques:

- Nearly adiabatic, approaching 40% thermodynamic efficiency
- Advanced finishing and coating solutions (PTWA, LDS, APS, DLC, etc)
- Roller-bearings for camshaft, balancing shaft, and even crankshaft
- Cylinder deactivation, variable valve timing, variable compression, electric accessories, etc.





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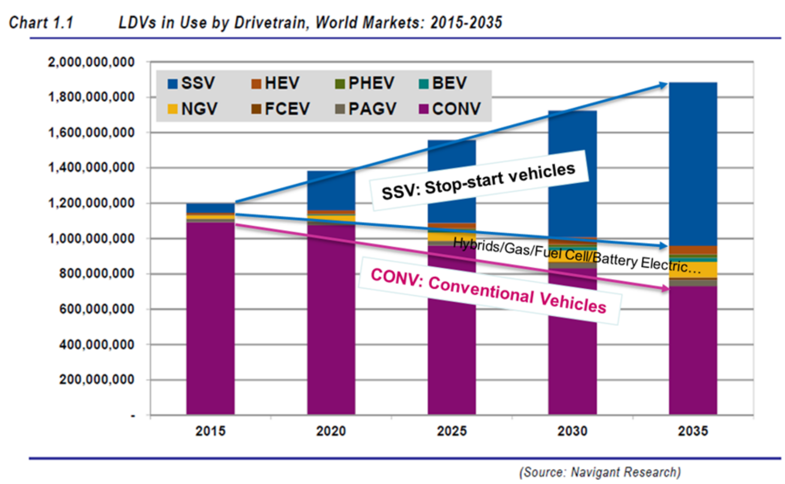
Engine Trend: Start-Stop



Stop-**S**tart **V**ehicles
Hybrid **E**lectric **V**ehicles
Plug-in **H**ybr. **E**lectric **V**eh.
Battery **E**lectric **V**ehicles
Natural **G**as **V**ehicles
Fuel **CE**ll **V**ehicles
Propane **A**uto**G**as **V**ehicles
CONVentional **V**ehicles

Bearings will have to withstand 300,000 instead of 30,000 start-stops

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Why we need new lubricants?

(i) More complex and delicate engine hardware requires higher quality lubricants and maintenance

- ❑ Exacting technical requirements
- ❑ Constancy in the lubricant properties across different markets
- ❑ Constancy in the lubricant properties over the service time
- ❑ Manufacturing capability to deliver the above

(ii) Supply situation is changing
(REACH, API Group I declines, Groups II-V grow)

(iii) Fuel quality is changing (low sulfur, oxygenated, bio)

(iv) Strong incentives to go green, renewable, energy-savvy

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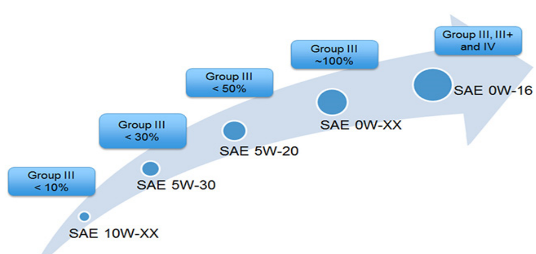
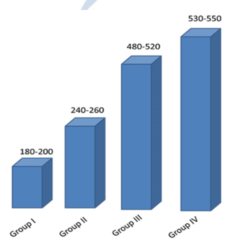
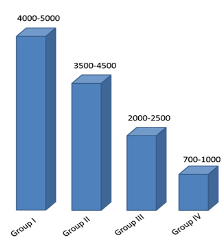
New performance requirements call for synthetics

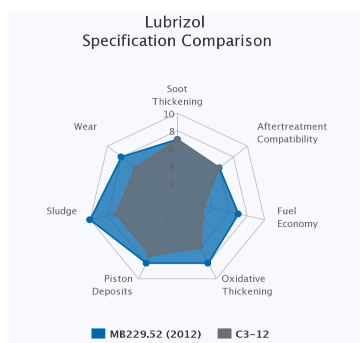




RBOT



CCS at -25C



Spec.	HTHS (cP) SA (%)	SA (%)	P (%)	S (%)	Min T
MB229.52 (2012)	≥3.5	≤0.8	0.05 to 0.09	≤0.3	≥6.0
C3-12	≥3.5	≤0.8	0.07 to 0.09	≤0.3	≥6.0

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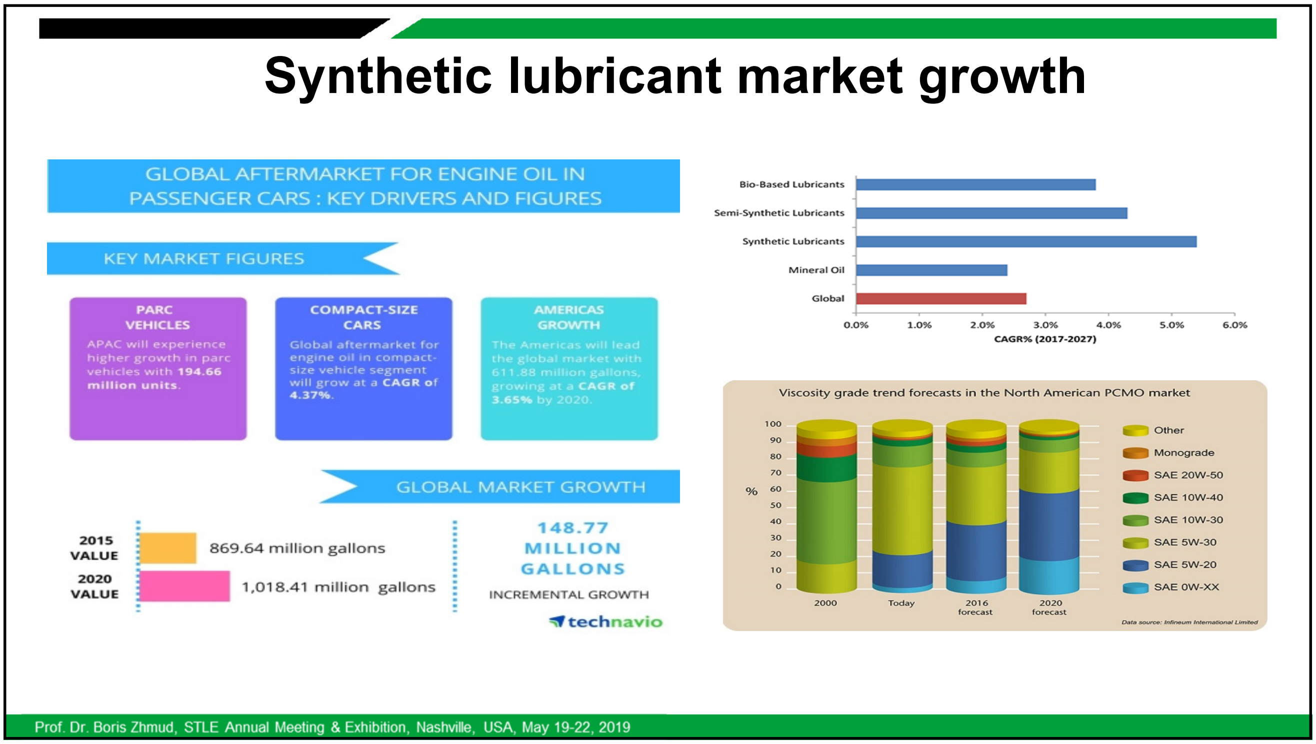
Synthetic lubricant market growth
GLOBAL AFTERMARKET FOR ENGINE OIL IN PASSENGER CARS : KEY DRIVERS AND FIGURES
KEY MARKET FIGURES
PARC VEHICLES
APAC will experience higher growth in parc vehicles with 194.66 million units.
COMPACT-SIZE CARS
Global aftermarket for engine oil in compact-size vehicle segment will grow at a CAGR of 4.37%.
AMERICAS GROWTH
The Americas will lead the global market with 611.88 million gallons, growing at a CAGR of 3.65% by 2020.
GLOBAL MARKET GROWTH
2015 VALUE
869.64 million gallons
2020 VALUE
1,018.41 million gallons
148.77 MILLION GALLONS
INCREMENTAL GROWTH
technavio
Bio-Based Lubricants
Semi-Synthetic Lubricants
Synthetic Lubricants
Mineral Oil
Global
0.0% 1.0% 2.0% 3.0% 4.0% 5.0% 6.0%
CAGR% (2017-2027)
Viscosity grade trend forecasts in the North American PCMO market
%
2000
Today
2016 forecast
2020 forecast
Other
Monograde
SAE 20W-50
SAE 10W-40
SAE 10W-30
SAE 5W-30
SAE 5W-20
SAE 0W-XX
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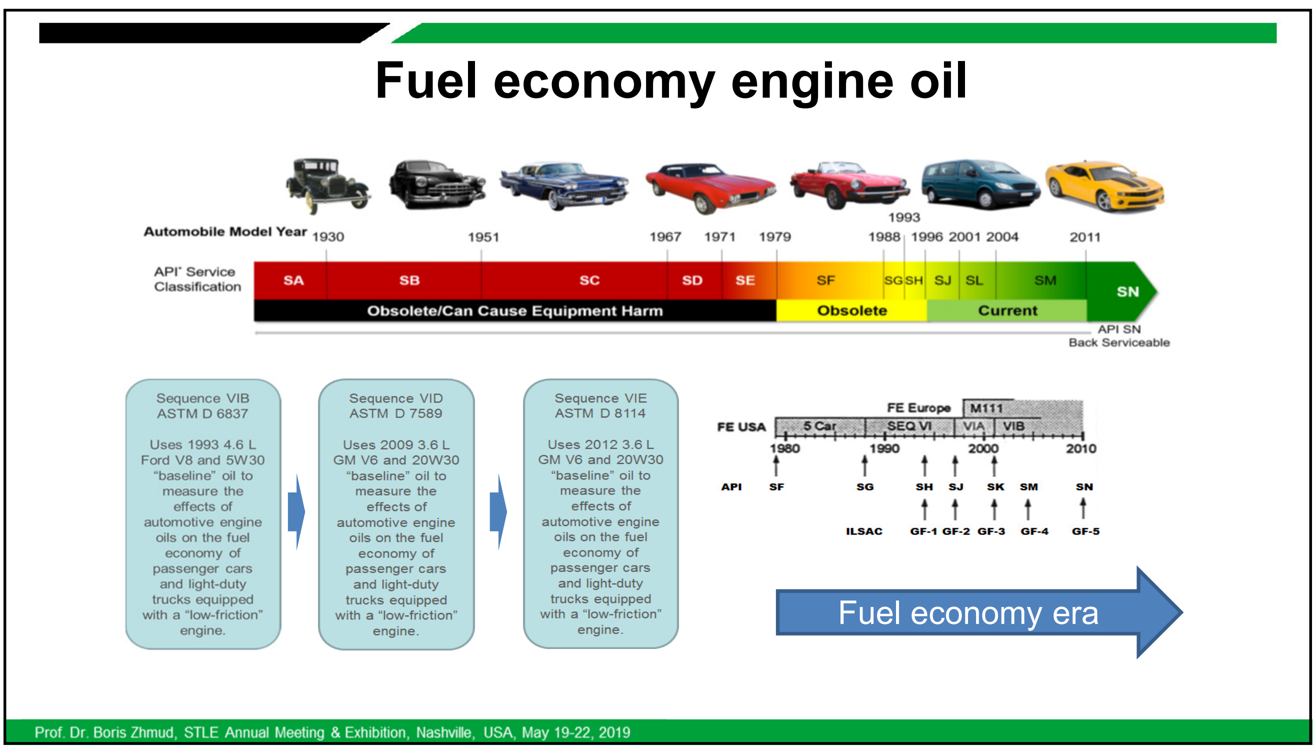
Fuel economy engine oil
Automobile Model Year
1930 1951 1967 1971 1979 1988 1993 1996 2001 2004 2011
API Service Classification
SA SB SC SD SE SF SG SH SJ SL SM SN
Obsolete/Can Cause Equipment Harm
Obsolete
Current
API SN Back Serviceable
Sequence VIB ASTM D 6837
Uses 1993 4.6 L Ford V8 and 5W30 "baseline" oil to measure the effects of automotive engine oils on the fuel economy of passenger cars and light-duty trucks equipped with a "low-friction" engine.
Sequence VID ASTM D 7589
Uses 2009 3.6 L GM V6 and 20W30 "baseline" oil to measure the effects of automotive engine oils on the fuel economy of passenger cars and light-duty trucks equipped with a "low-friction" engine.
Sequence VIE ASTM D 8114
Uses 2012 3.6 L GM V6 and 20W30 "baseline" oil to measure the effects of automotive engine oils on the fuel economy of passenger cars and light-duty trucks equipped with a "low-friction" engine.
FE Europe M111
FE USA 5 Car SEQ VI VIA VIB
1980 1990 2000 2010
API SF SG SH SJ SK SM SN
ILSAC GF-1 GF-2 GF-3 GF-4 GF-5
Fuel economy era
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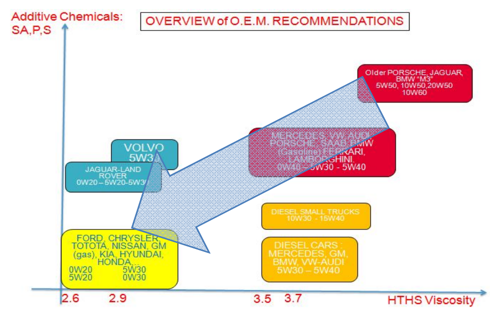
ULVO and fuel economy

- ✓ Availability of synthetic oils
- ✓ New engineering solutions

SAE J300 - Revised January 2015

SAE Viscosity Grade	Low Temp. Cranking (cP)	Low Temp. Pumping (cP)	Minimum Kinematic (cSt)	Maximum Kinematic (cSt)	Hi-Temp. Hi-Shear (cP)
0W	6,200 @ -35°C	60,000 @ -40°C	3.8	-	-
5W	6,600 @ -30°C	60,000 @ -35°C	3.8	-	-
10W	7,000 @ -25°C	60,000 @ -30°C	4.1	-	-
15W	7,000 @ -20°C	60,000 @ -25°C	5.6	-	-
20W	9,500 @ -15°C	60,000 @ -20°C	5.6	-	-
25W	13,000 @ -10°C	60,000 @ -15°C	9.3	-	-
8	-	-	4	<6.1	1.7
12	-	-	5	<7.1	2.0
16	-	-	6.1	<8.2	2.3
20	-	-	6.9	<9.3	2.6
30	-	-	9.3	<12.5	2.9
40	-	-	12.5	<16.3	3.5 (0W-40, 5W-40, 10W-40)
40	-	-	12.5	<16.3	3.7 (15W-40, 20W-40, 25W-40, 40 monogrado)
50	-	-	16.3	<21.9	3.7
60	-	-	21.9	<26.1	3.7

A trend towards low visc and low SAPS oils:



$$FE = \frac{3.7 - HTHS}{3.7} \times 15\%$$

Move from 10W-40 to 0W-20 gives 4-5 % gain in FE (NEDC)

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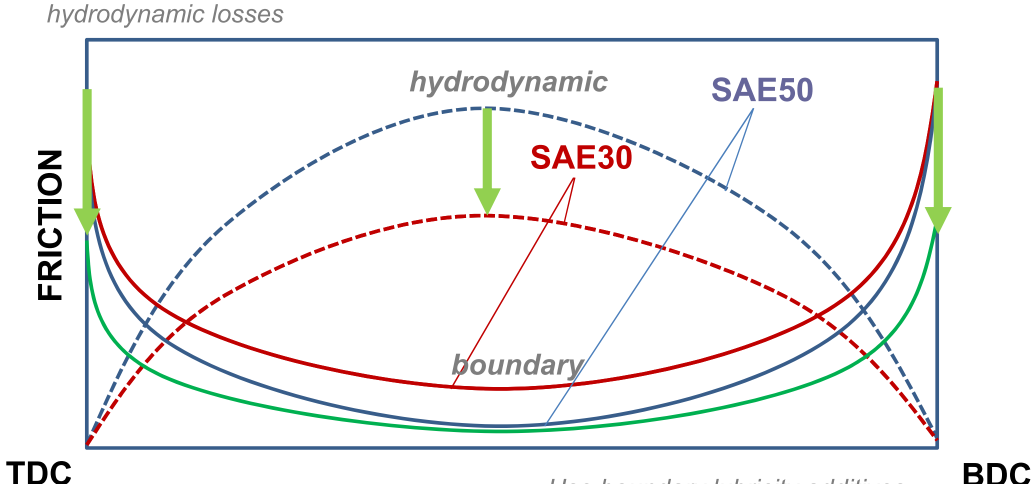
This is how it works

Use lower viscosity to minimize hydrodynamic losses



Use boundary lubricity additives to control wear & boundary friction

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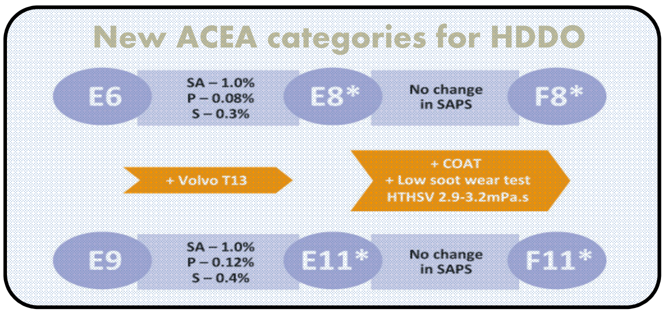
New and future oil categories

2016 → 2017 → 2018 → 2019 → 2020

2016: API CK-4, FA-4, ACEA C5

2018: API SN Plus, ACEA E8 / F8, ACEA E11 / F11

2020: ILSAC GF6 on its long and thorny way

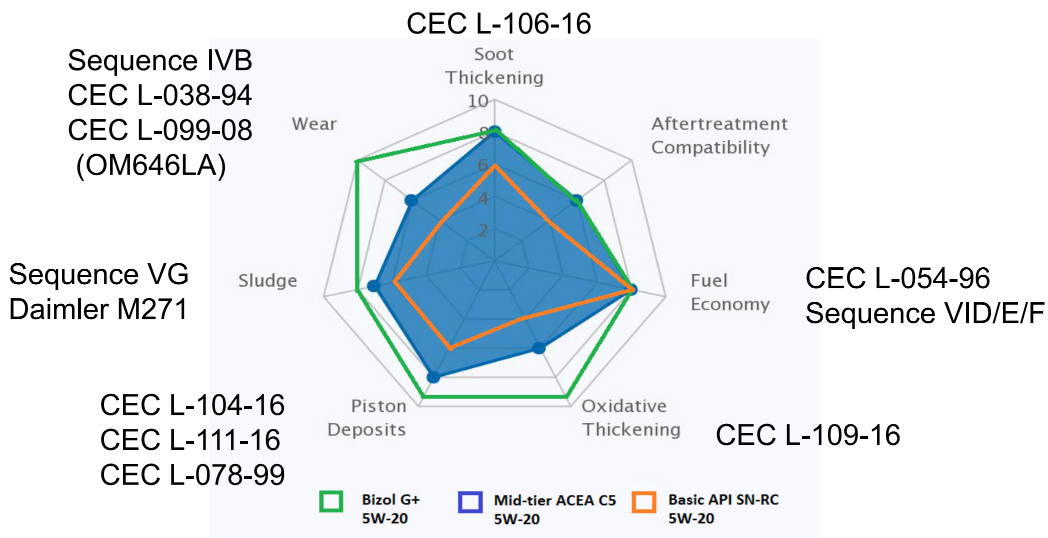


Under development: lubricants for hybrid electric transmissions

New additive types

- ✓ EP/AW additives (B, Mo, W, Ti) to compensate for reduced P level
- ✓ EP/AW additives (B, Mo, W, Ti) to control timing chain wear
- ✓ EP/AW additives compatible with oxygenated base oils and fuels
- ✓ Boundary lubricity additives to compensate for reduced film thickness
- ✓ Superlubricity additives and boundary VI improvers
- ✓ Partial substitution of Ca by Mg and Na to ensure adequate LSPI protection
- ✓ Low-ash and ashless dispersants to better handle soot in low SAPS formulations
- ✓ Solvency boosters
- ✓ New antioxidants optimized for esters and OSPs

The challenge is to find the right balance



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