Synthetic Lubricants in North America

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Topics

- Synthetic Definition Globally
- Synthetics in North America and PAO Impact
- Current Performance Attributes of Varying Degrees of Synthetics

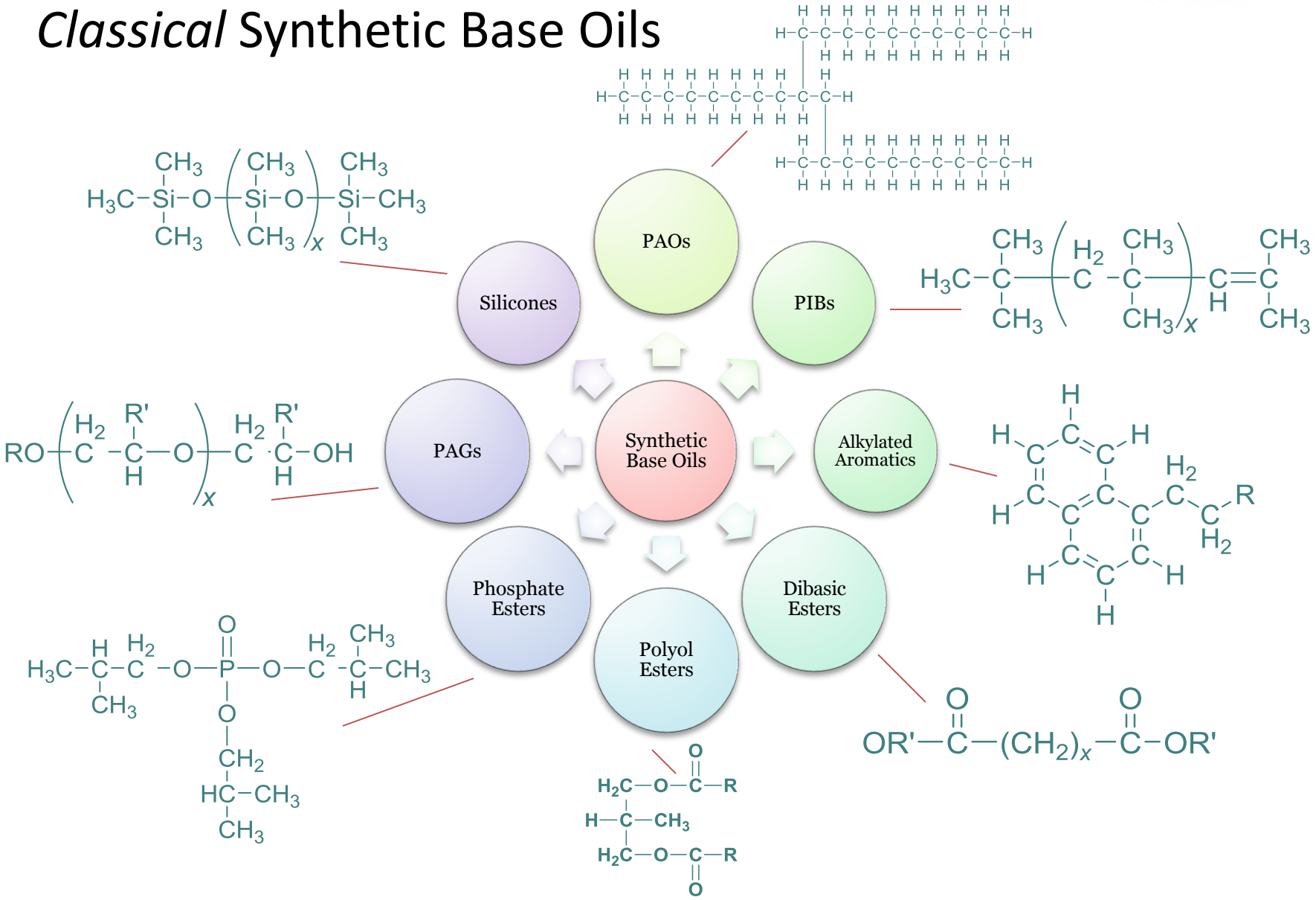
What is *Synthetic*?

- This Chemist's opinion:
  - Origin and etymology of the word synthetic
    - Greek: *synthetikos* of composition, component, from *syntithenai* to put together
  - "Man-made" / "Tailored"
  - Made by combining low molecular weight materials via chemical reaction into higher molecular weight materials
- Engine oil view of synthetic may be different than other lubricant application views
- World / Regional Differences
  - US – marketing term
  - Germany – strict definition
  - Japan – strict definition
- Does 100% synthetic really mean 100%?

Is a *Name* just a *Name*: Synthetic (it depends)

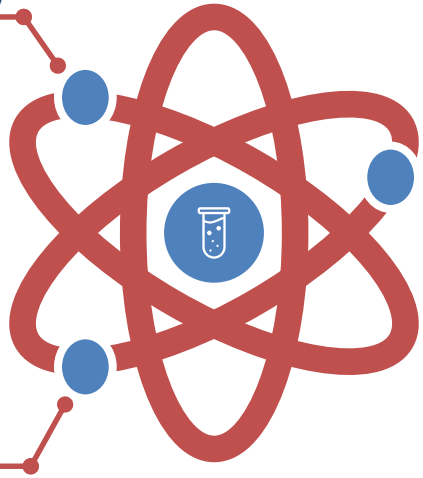
- German Law requiring transparency in “Fully Synthetic” and “Partial Synthetic”
- Non-binding National Advertising Division of the Better Business Bureau (1997) in US rendered *synthetic* as a marketing term
  - *Is there a slippery slope as to what is synthetic?*
- NAD applies to automotive not industrial or other lubricant areas (i.e. metal working fluids)

Classical Synthetic Base Oils



Demand & Trend drivers

Engine oil specifications are driving base oil quality



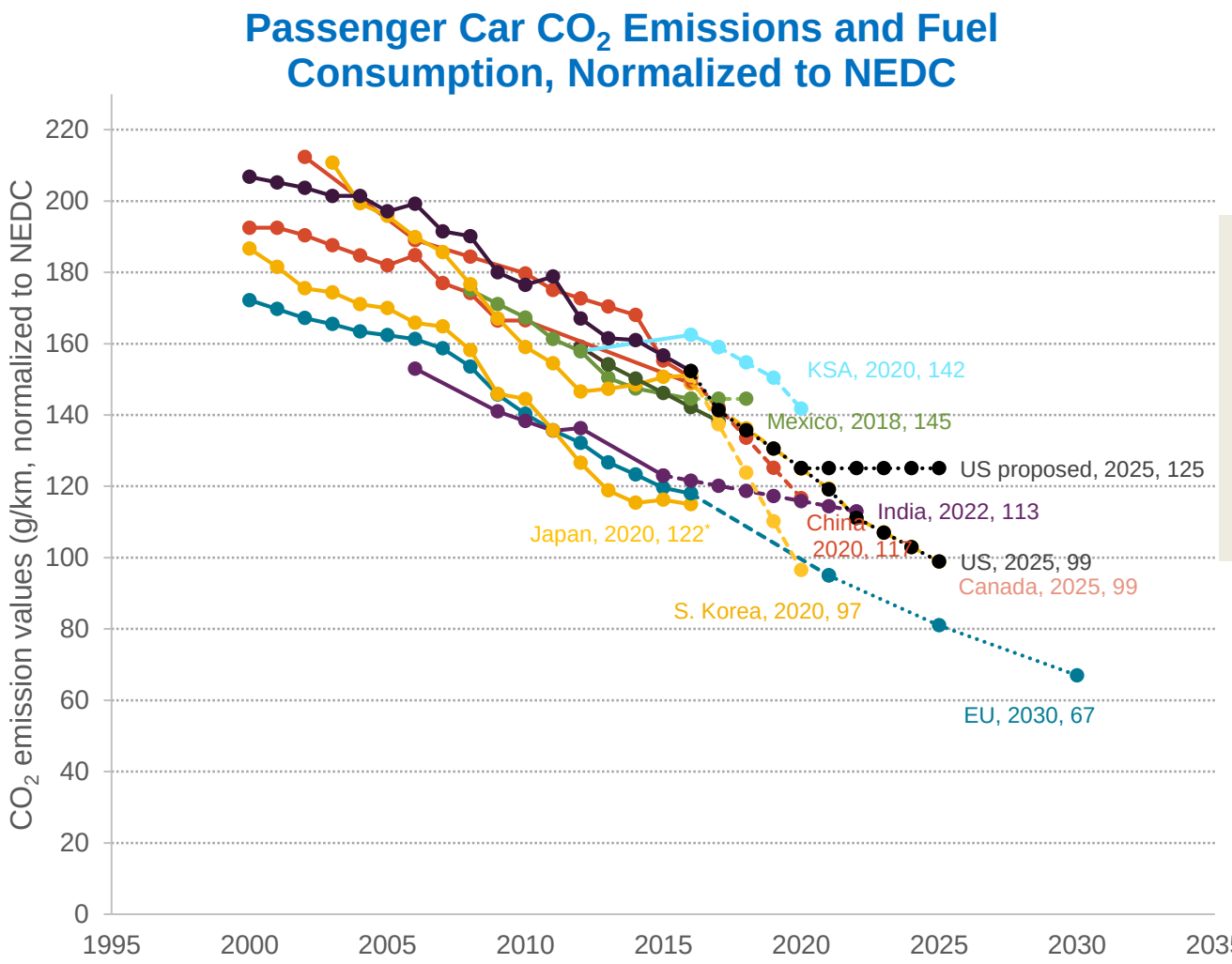
Changing emissions legislation continues to accelerate new formulations

EU Commission proposal for post-2020 CO_2 targets for cars and vans:
- 2025: 15% reduction
- 2030: 30% reduction

Fuel economics & energy efficiency

- Continued push towards lighter viscosity oils
- Future viscosity requirements going to 0W-20 and below

Global Fuel Efficiency Goals

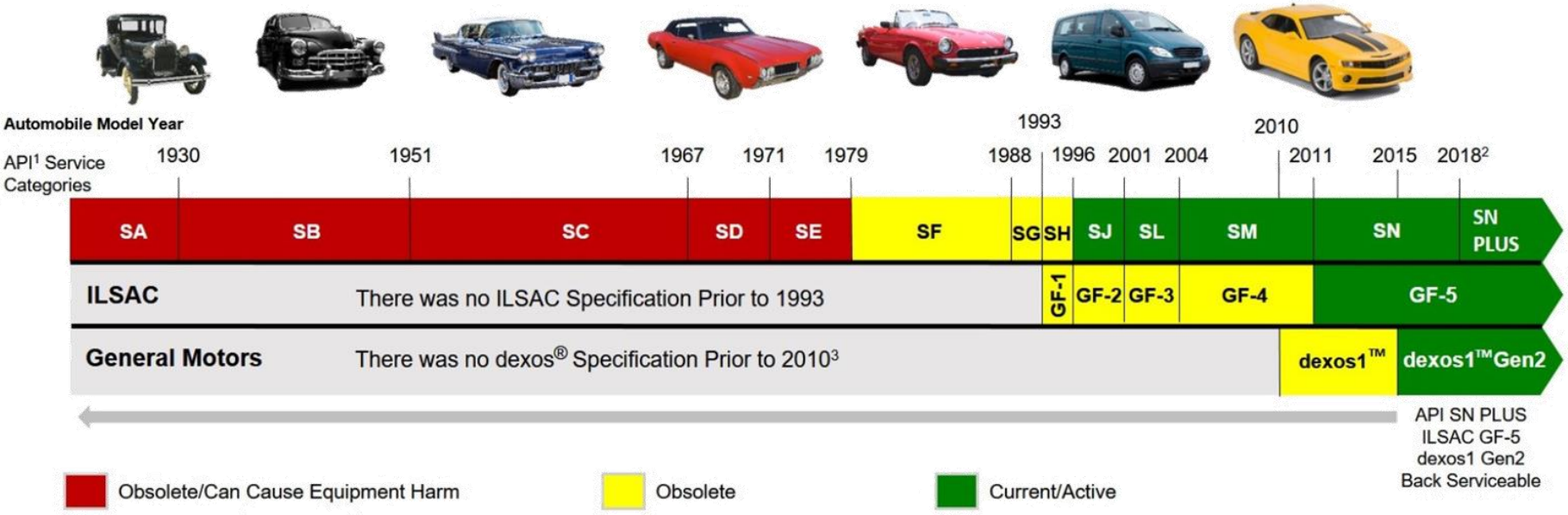


"The ICCT approach converts each region's test numbers to a common (NEDC) test cycle based on modelling estimates. Therefore these are not the official numbers from each country's own testing system. For additional comparisons see IES 2008b."

Source: 50BY50 Global Fuel Economy Initiative "*Making Cars 50% More Fuel Efficient by 2050 Worldwide*" http://www.mlit.go.jp/common/000053581.pdf FIA Foundation for the Automobile and Society.
NEDC: New European Driving Cycle
ICCT: International Council on Clean Transportation www.theicct.org
* Note that Japan has already met its 2020 statutory target as of 2013

North America: Synthetic vs. Conventional Engine Oil

- Key Findings from AAA study[1] on the differences between conventional and synthetic engine oil:
  - On average, synthetic oils outperformed conventional oils in the conducted tests by 47 % on: shear stability, deposit formation, volatility, cold-temperature pumpability, oxidation resistance, and oxidation-induced rheological changes
  - 44 % of drivers are either not sure if synthetic motor oil is better for their engine, or do not believe synthetic motor oil is better for their engine



1 - AAA Engine Oil Research: AAA Proprietary research into the differences between conventional and synthetic engine oil, May 2017, NewsRoom.AAA.com

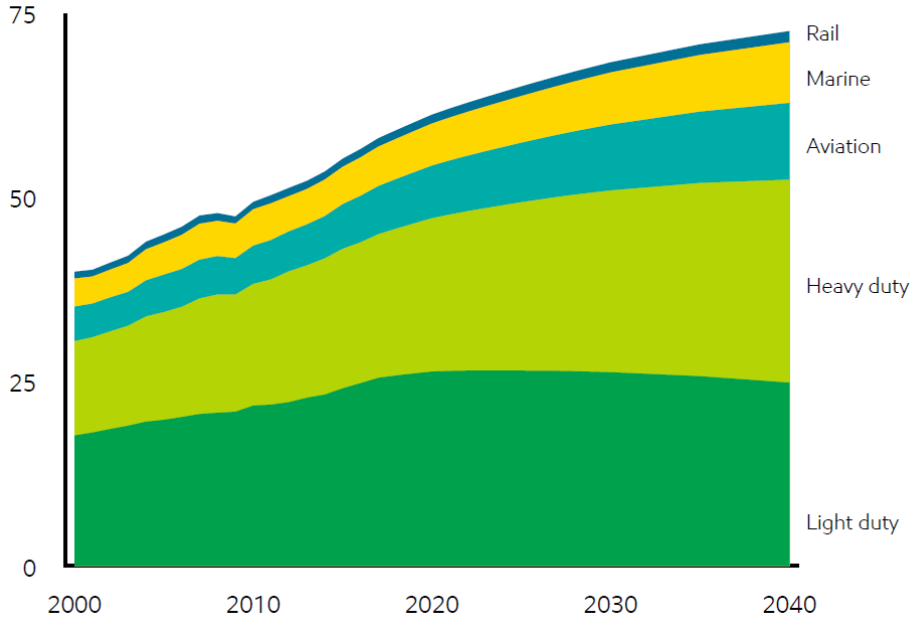
2 – API service chart from a series of PQIA Quick reference guides

Heavy Duty Engine Oil

- Heavy duty = largest demand in transportation sector
  - 5% AAGR Growth
- Synthetics use will grow due to
  - Stricter fuel economy regulations
  - Cost savings from increased fuel efficiency
  - Increased drain intervals
- 15W-40 Consumption in North America:
  - 2016: 74% of market
  - 2027: 40% of market
- European OEMs are factory filling trucks with full synthetic (5W-30) and semi-synthetic (10W-30)
  - U.S. is primarily moving towards 10W-30

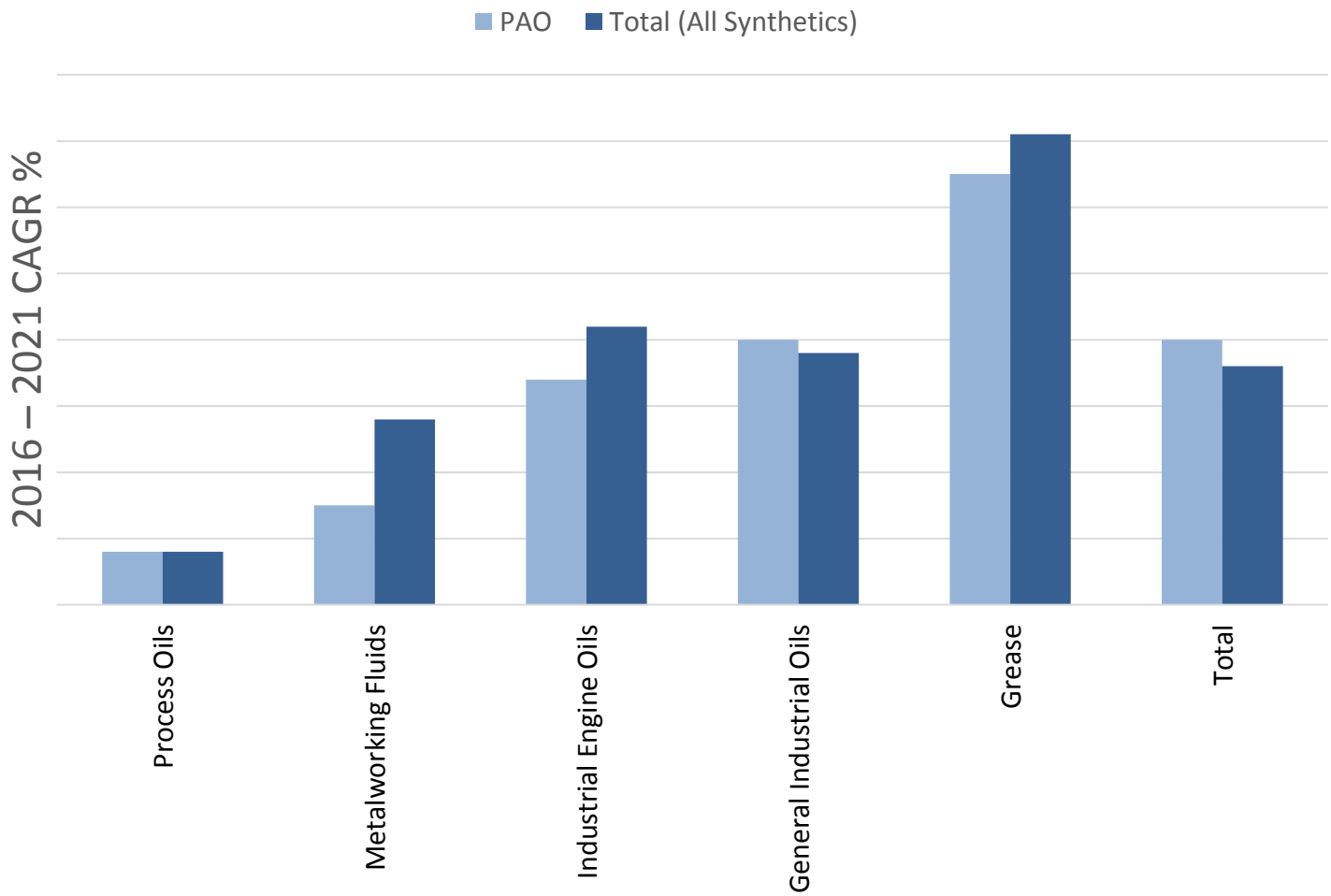
Energy Demand – Transportation Sector

Global sector demand – million oil-equivalent barrels per day (MBDOE)



Source: Lubes and Greases Nov 2017 & ExxonMobil 2018 *Outlook for Energy: A View to 2040*

Global Synthetic Base Stock Consumption Growth

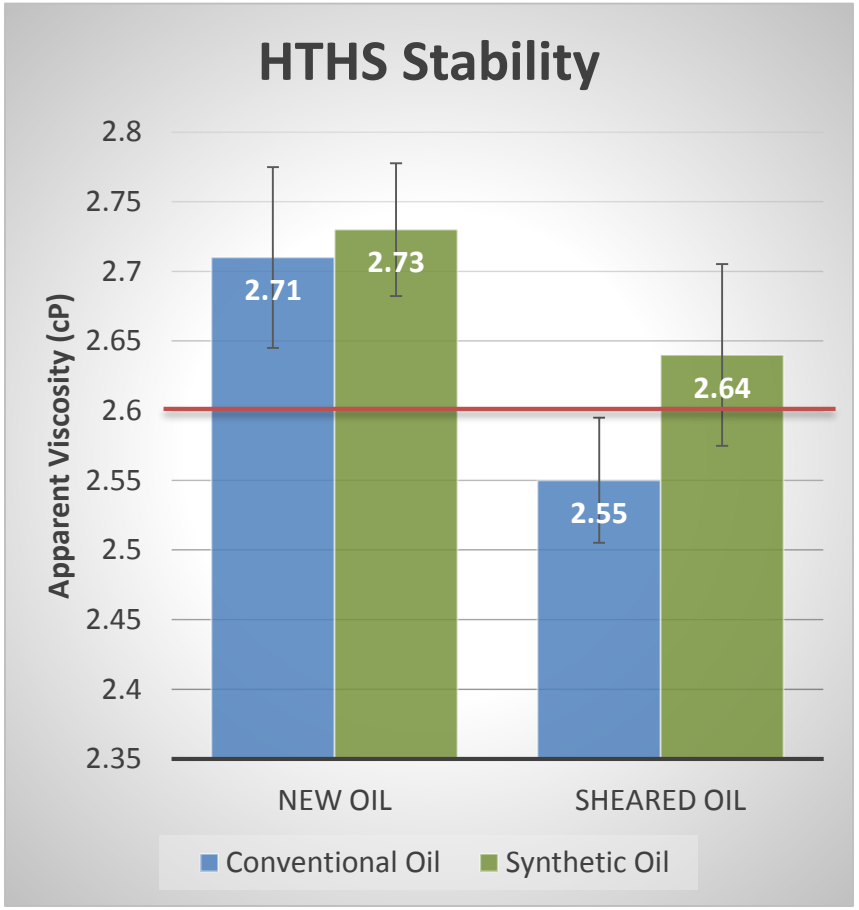


Source: Kline

HTHS Shear Stability

- Conventional and synthetic 5W-20 oils were evaluated (5 of each type) by AAA[1]
- All of the conventional oils tested fell below the ILSAC GF-5 minimum (2.6 cP) while 4/5 of the synthetic oils remained above the minimum.
- ILSAC GF-5 specification is for new oils but:

  "engine wear can be adversely affected if an engine oil exhibits poor HTHS stability throughout its service life"[2]

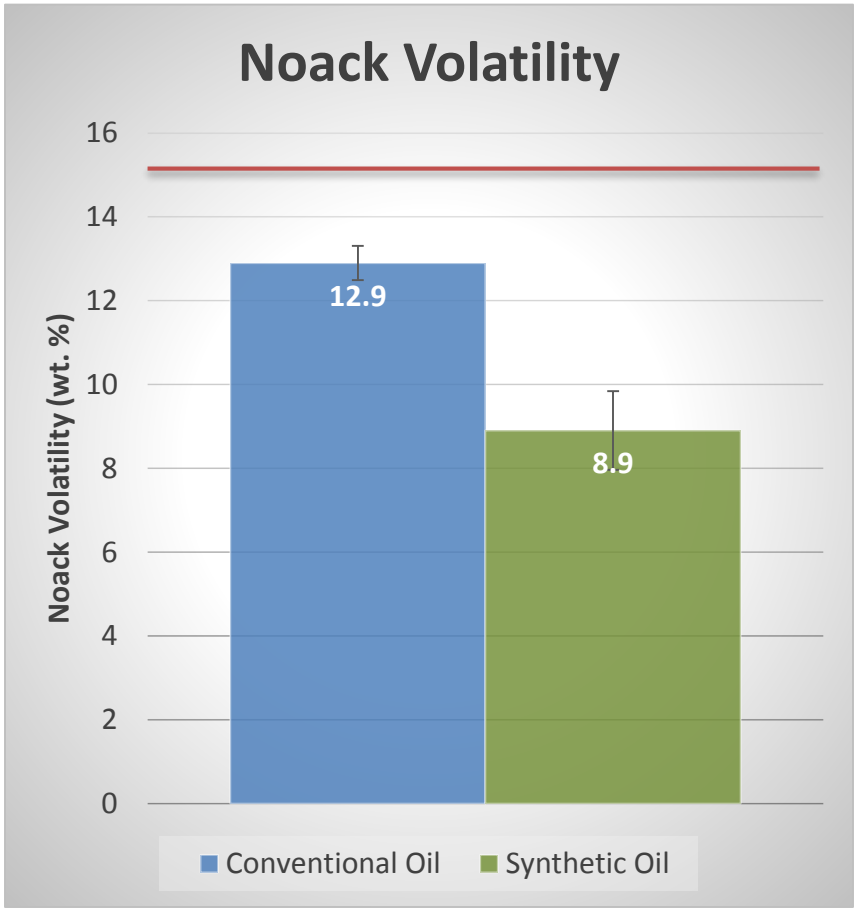


1 - AAA Engine Oil Research: AAA Proprietary research into the differences between conventional and synthetic engine oil, May 2017, NewsRoom.AAA.com

2 - M. J. Covitch, "Olefin Copolymer Viscosity Modifiers," in Lubricant Additives: Chemistry and Applications, Second Edition, CRC Press, 2009, pp. 283-310.

Noack Volatility

- Conventional and synthetic 5W-20 oils were evaluated (5 of each type) by AAA[1] by the Selby-Noack volatility method.
- Although all of the tested oils are below the ILSAC GF-5 limit of 15% weight loss the synthetic oils were all significantly below the conventional oils.
- On average, the 46% higher volatility of the conventional oils is likely due to the greater presence of lower molecular weight compounds.[1]

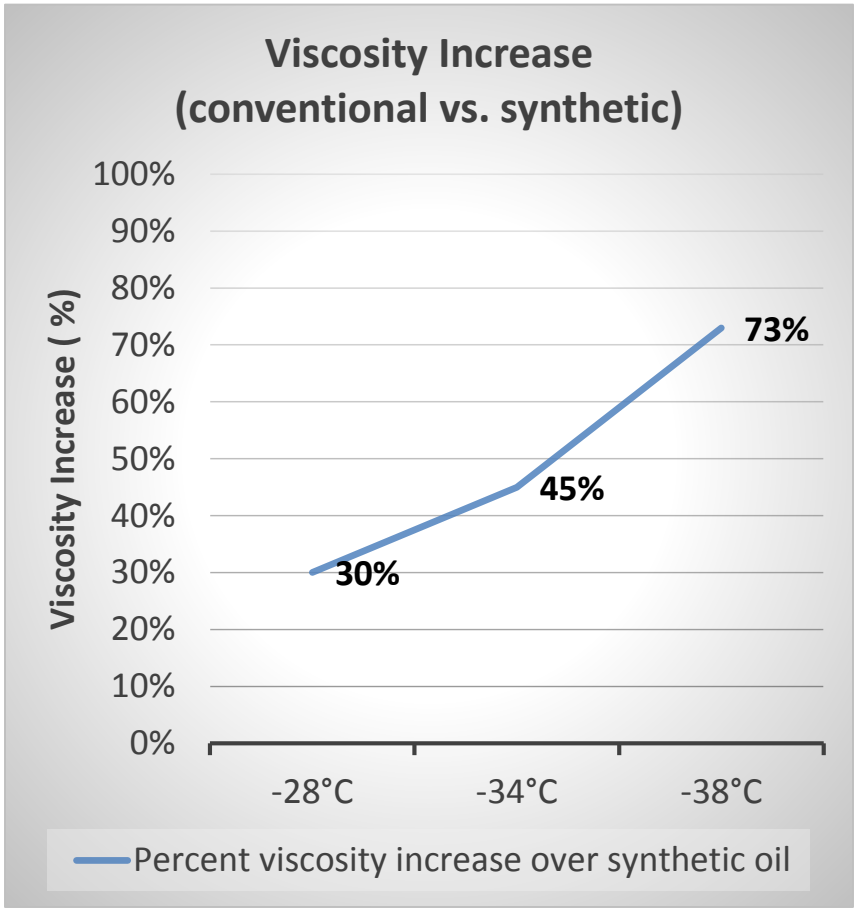


1 - AAA Engine Oil Research: AAA Proprietary research into the differences between conventional and synthetic engine oil, May 2017, NewsRoom.AAA.com

Scanning Brookfield

- Conventional and synthetic 5W-20 oils were evaluated (5 of each type) by AAA[1] by the Scanning Brookfield method.
- Depending upon the oil flow design, "a high low-temperature/low-shear viscosity may result in flow-limited behavior and subsequent engine damage".[1]
- Flow-limited behavior is associated with viscosity and is not dependent on gelation.[3]

Estimated Viscosity (cP)	-28°C	-34°C	-38°C
Conventional	6,943	16,966	34,667
Synthetic	5,357	11,677	20,000



1 - AAA Engine Oil Research: AAA Proprietary research into the differences between conventional and synthetic engine oil, May 2017, NewsRoom.AAA.com

3 - ASTM International, Standard Test Method for Low Temperature, Low Shear Rate, Viscosity/Temperature Dependence of Lubricating Oils Using a Temperature Scanning Technique, D5133 - 15 ed.

Summary

- The term “Synthetic” covers a wide variety of materials
- In automotive applications, synthetic has become a marketing term (US)
- Synthetic engine oils have been demonstrated to have significant advantages in:
  - Shear stability
  - Noack volatility
  - Oxidation resistance (including oxidation-induced rheological changes)
  - Low temperature performance (CCS, low temperature pumping and scanning Brookfield viscosities)

Questions?

Thank You!

Chevron Phillips Chemical Company LLC