

# **The Growing Demand for High Vis PAO within Asia**

**Tony Qian**

**Customer Technical Service and Market  
Development Scientist  
INEOS Singapore**

**INEOS  
Oligomers**

# AGENDA

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## The Growing Demand for High Vis PAO Synthetics within Asia

**PAO General information**

**High Vis PAO Applications**

**Compressor Oil**

**Industrial Gear Oil & Wind Turbine Oil**

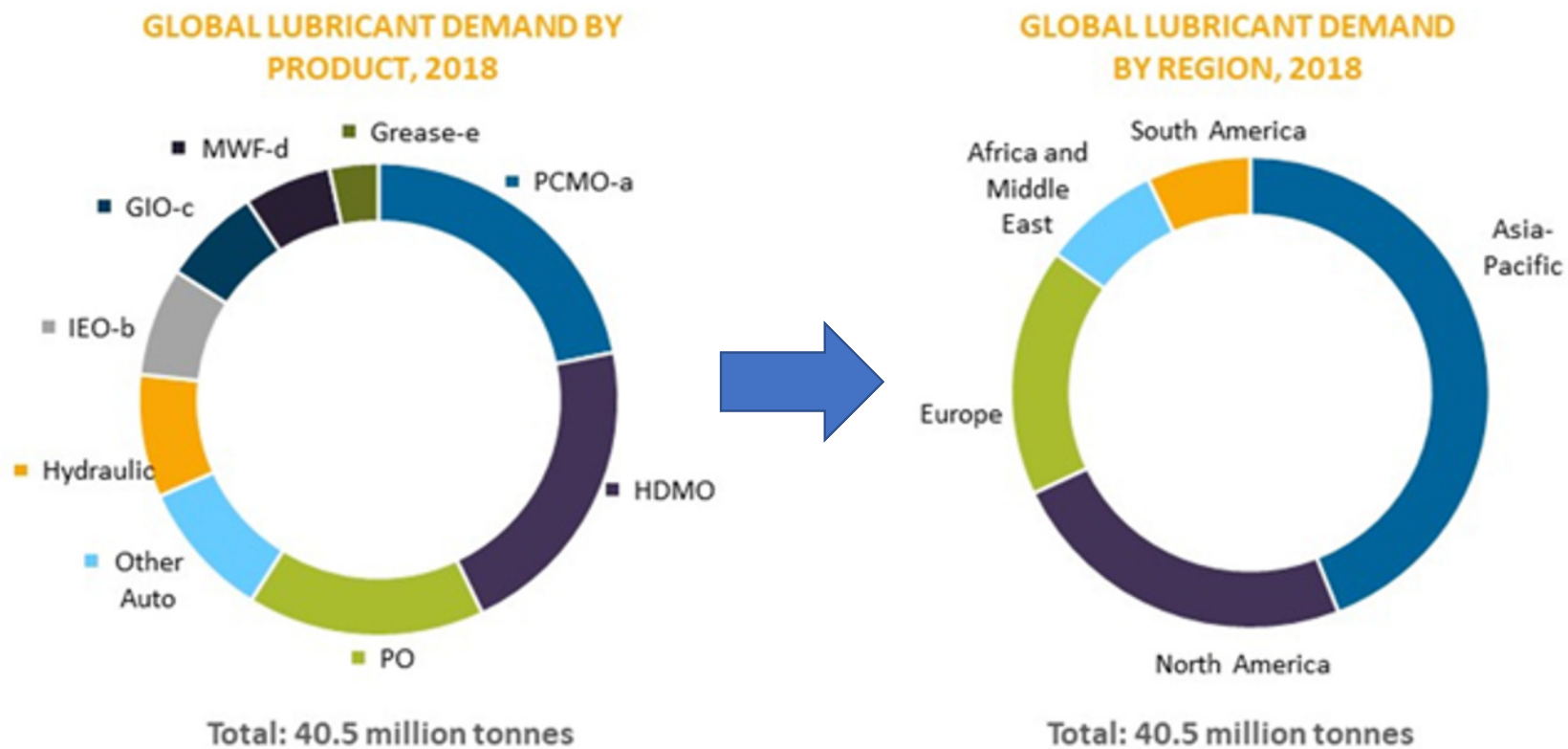
**Ineos New PAO Project**



# PAO General information

# General information

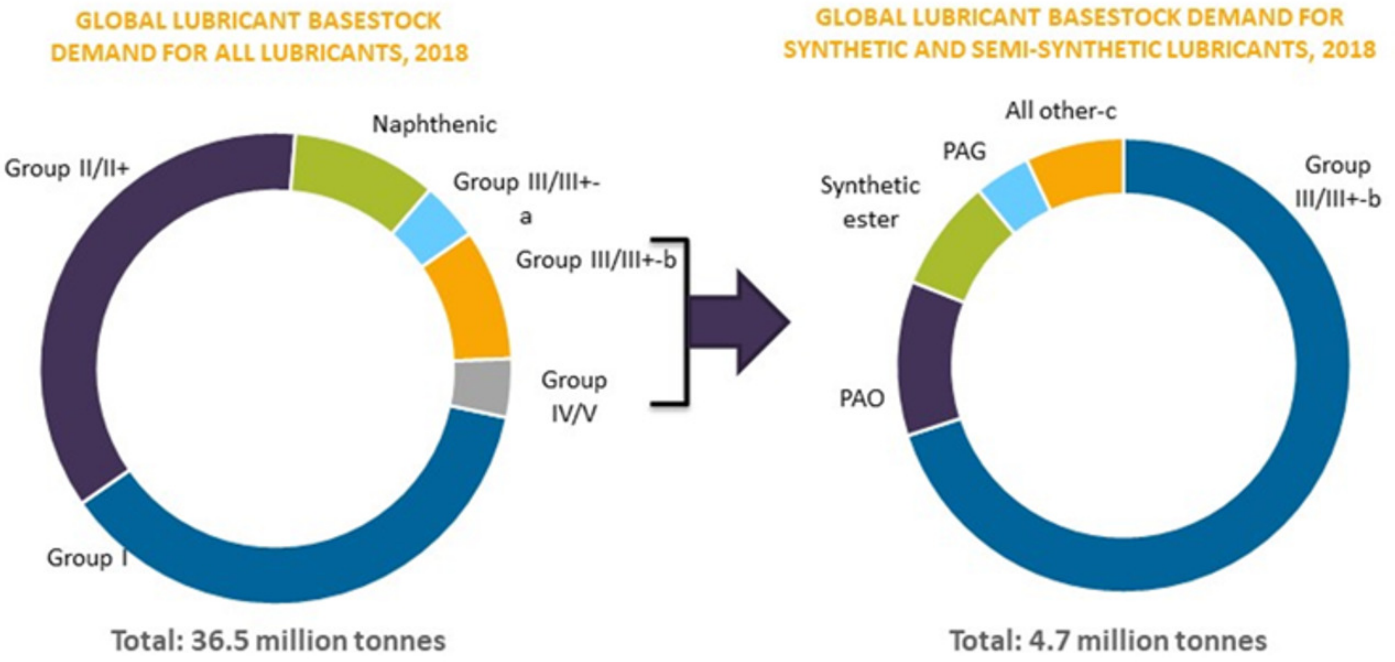
Kline estimates that global finished lubricant demand at 40.5 million tons in 2018



Source: Kline Webinar: Global Lubricant Basestocks Market Trends by Anuj Kumar at Oct 9, 2019

# General information

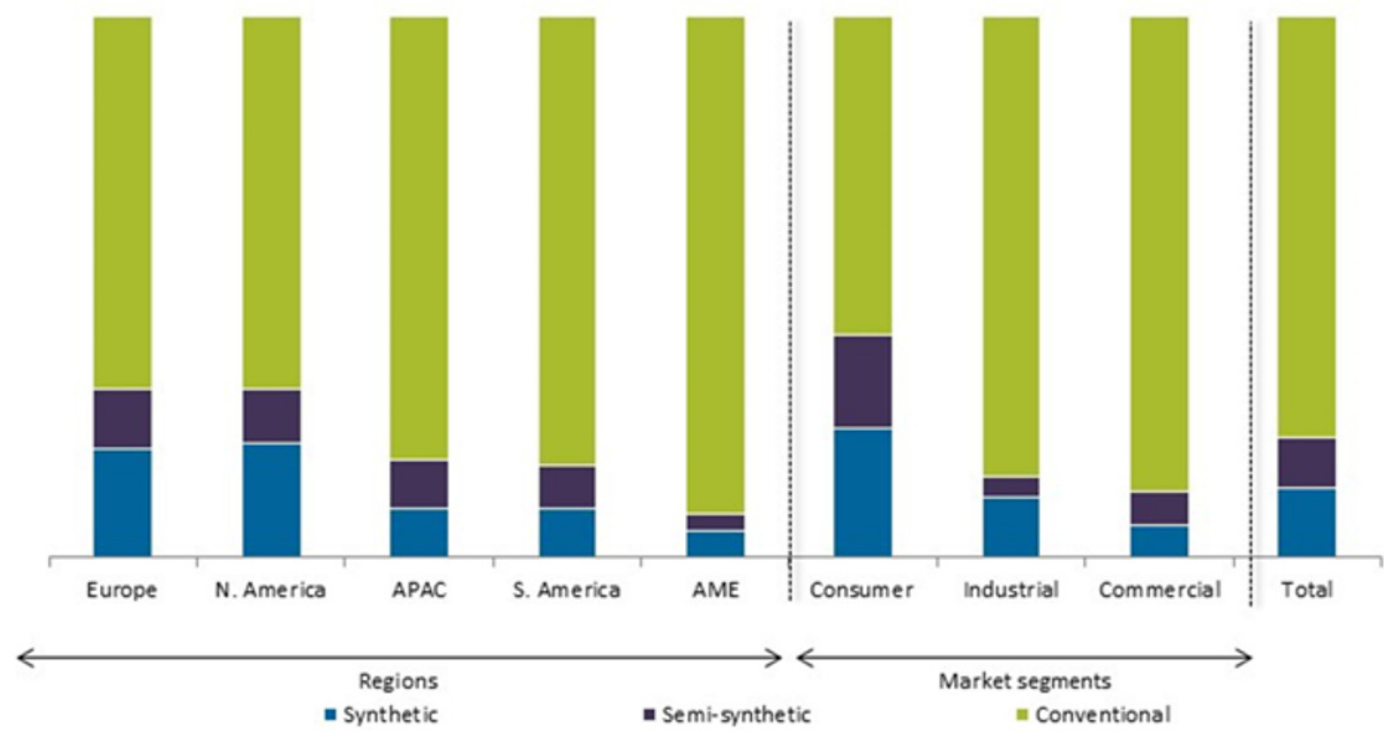
Kline estimates global base stock demand at 36.5 million tons in 2018; Synthetic and semi-synthetics represent 13% of this total.



Source: Kline Webinar: Global Lubricant Basestocks Market Trends by Anuj Kumar at Oct 9, 2019

# General information

## PENETRATION OF SYNTHETIC AND SEMI-SYNTHETIC LUBRICANTS BY REGION AND PRODUCTS, 2018



Source: Kline Webinar: Global Lubricant Basestocks Market Trends by Anuj Kumar at Oct 9, 2019

# General information

## Synthetic Lube Market Edges Up- George Gill

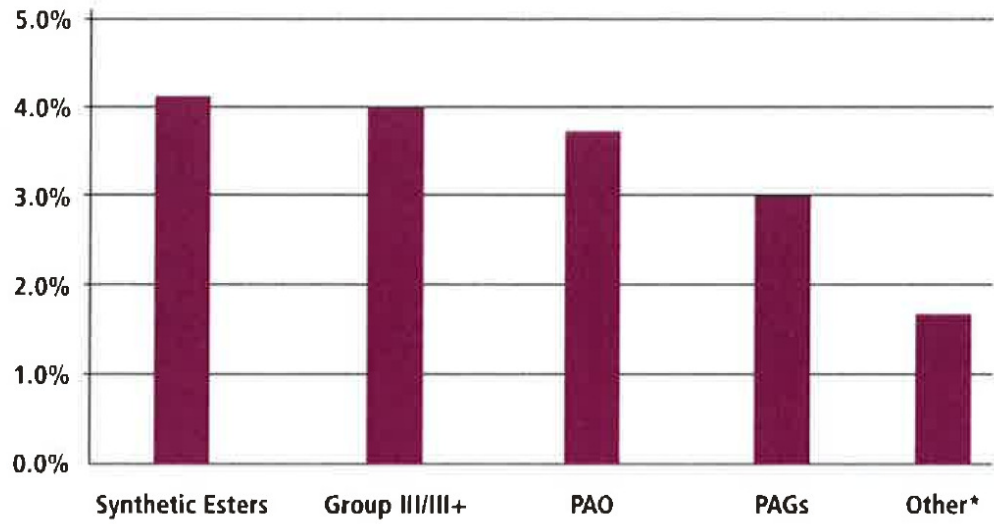
Lubes 'N Greases MENA, February 2017

The main PAO drivers are OEM technical demand, emission and fuel economy regulations, extended oil drain intervals, and so on.

**Synthetic Lubricant Base Stock Demand Growth, 2015-2020**

Source: Kline & Co.

\* PIB, phosphate esters, alkylated aromatics, and other base stocks



## General information

### Hi Vis PAO Segments

High Vis PAOs represent a small part of the total PAO market, and it work as viscosity builders for finished lubricants in the ISO 22 to ISO 460 range.

Before High Vis PAOs were only available in two viscosity grades, 40 cSt and 100 cSt.

However, with the new metallocene catalyst technology, it is now feasible to manufacture 1,000 cSt and above.

The key market for High Vis PAOs is industrial lubricants.

### High Vis PAO Market Segments

#### *Lubricants*

- Industrial  
Gear, Grease, Compressor
- Transportation  
Gear, Manual transmission
- Wind Turbine  
Gear, Grease

#### *Cable Compound*

Fiber optic compounds

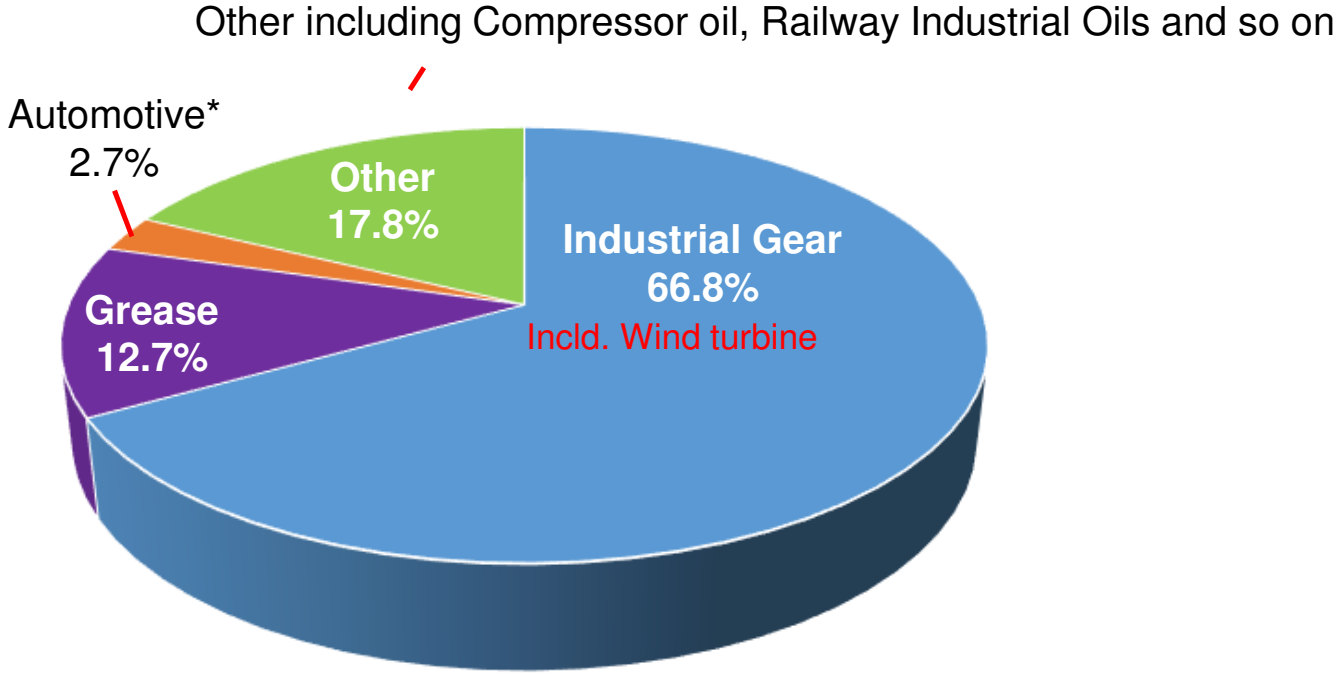
#### *Other*

Cosmetics, polymer modification



# High Vis PAO Applications

## Asian High Vis PAO Segmentation by Application



\*Automotive includes Continuous Variable Transmission Oils

## General information

# Advanced mPAO 10 Base Fluid

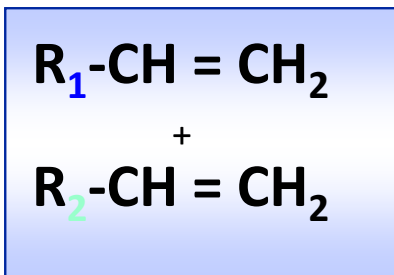
Metallocene technology can be used to produce decene-based 10 mm<sup>2</sup>/s PAOs with excellent low temperature performance

	Conventional PAO10 Typical Properties	New Metallocene Decene-based PAO 10
K. Viscosity @ 100°C	9.6	10.6
K. Viscosity @ 40°C	62.9	64.6
K. Viscosity @ -40°C	32,650	<b>21,870</b>
Viscosity Index	132	<b>155</b>
Pour Point, °C	-45	<b>-63</b>
Noack Volatility	3.5	<b>3.3</b>
Flash Point, °C	250	<b>263</b>

# General information

## Conventional High Vis PAOs

Conventional PAO



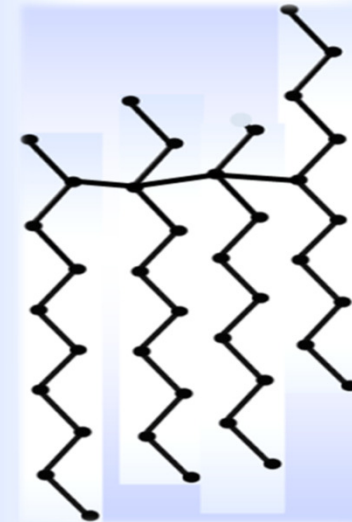
Alpha olefin

In-situ  
 $AlX_3$

A) Polymerization

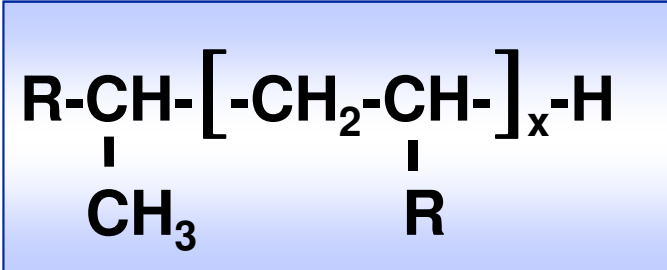
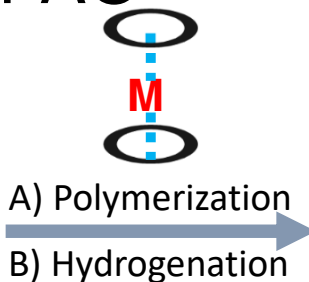
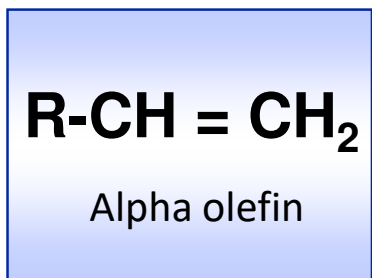
B) Hydrogenation

- ❖ Inconsistent Backbone Structure
- ❖ Poor Cold Cranking Viscosity
- ❖ Poor Brookfield Viscosity
- ❖ Poor Pour Point Properties

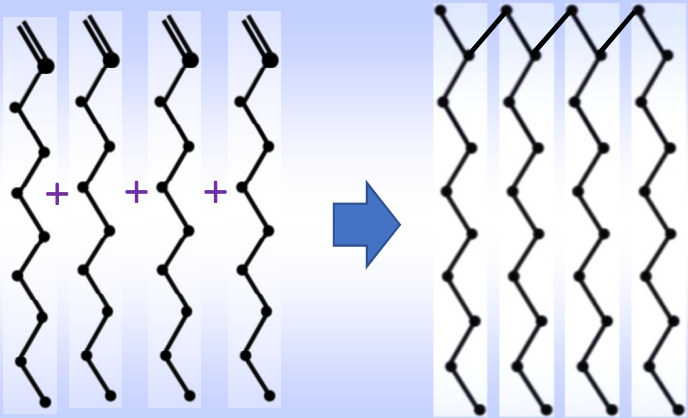


# General information

## Metallocene PAO

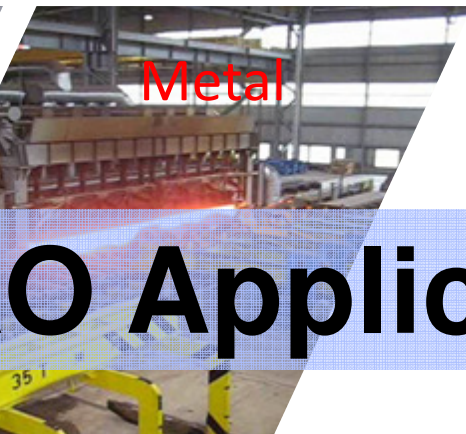


Hydrogenated oligomers



- ❖ Consistent Backbone
- ❖ No Mis-insertion Defects
- ❖ Excellent Thickening Power
- ❖ Superior Low Temp Prop.
- ❖ Shear Stable

Adapted from "Synthetic Base Stocks", mne.psu.edu/Chang



Wind Turbine

Conveyor

Metal

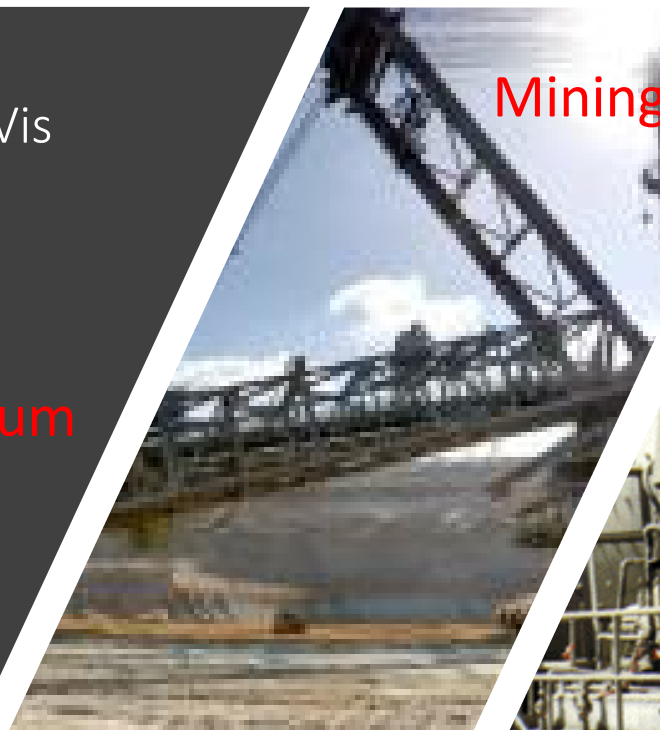
On Car

# High Vis PAO Applications

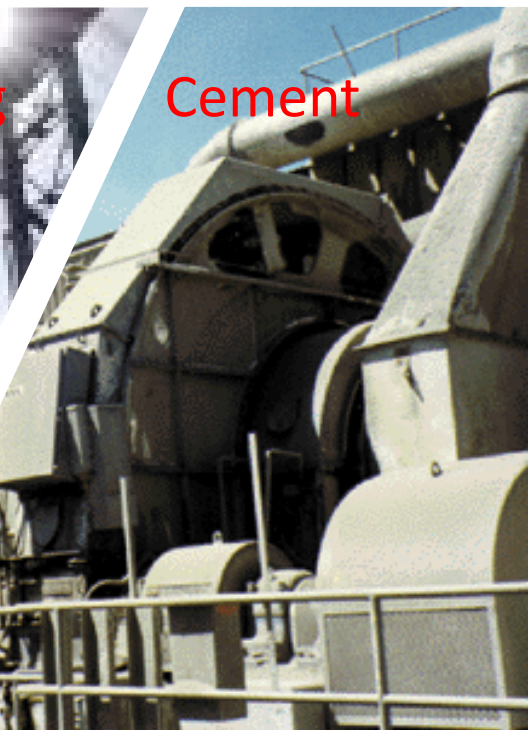
**Where & Why** are synthetic High Vis PAO used

- Higher load/Pressure
- Longer shelf life
- Better demulsification
- Better anti-oxidant performance
- Better lower temperature fluidity
- Better high temperature lubrication

**Premium**



Mining



Cement



# High Vis PAO Applications

## Mining Industry

Heavy..... Hot..... Cold..... Dust..... Rain..... Snow.....Less maintenance.....Long shelf life.....



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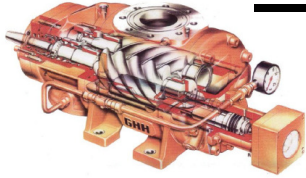


# Compressor Oil

- As a general rule, mineral-based compressor lubricants require oil changes after **500-1,000 hours** of service, while synthetic lubricants can be used in continuous operation in excess of **8,000 – 10,000 hours** of service

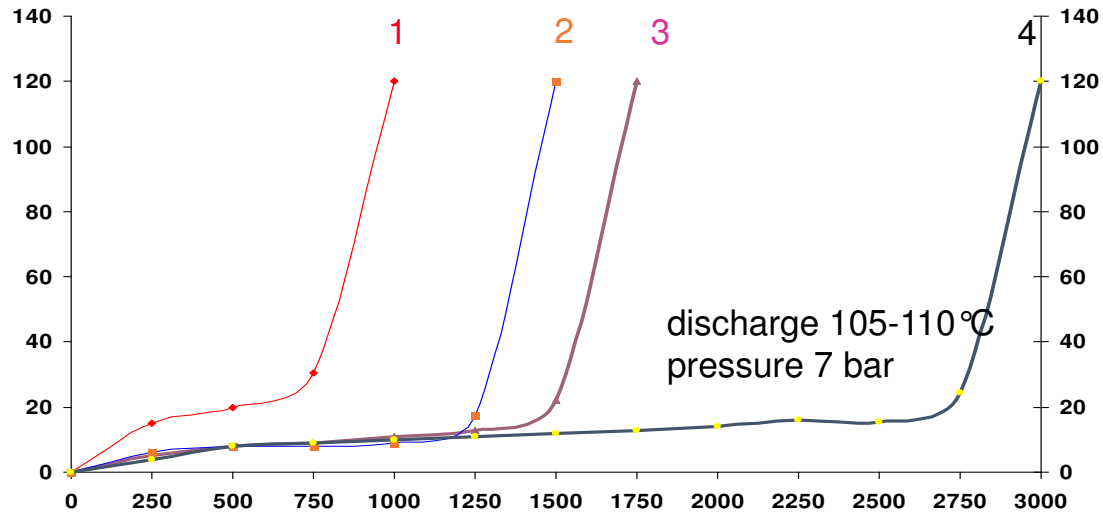
# Compressor Oil

## Compressor Life



- Oil 1 : Mineral based
- Oil 2 : Ester based
- Oil 3 : Part Synthetic
- Oil 4 : High Vis PAO

Viscosity Increase, %



Hours of Operation

Source: International Lubricants Week Moscow 11 – 14 Nov 2014



## Synthetic Compressor Oils

### 10,000-Hour Cost Comparison of PAO vs Mineral Rotary Screw Compressor Lubricants

### Advantages of PAO Synthetic Compressor Oils

- 1) Longer oil life (8,000 – 10,000 hours)
- 2) Low rates of deposit formation
- 3) Wide operating temperature range
- 4) Improved chemical resistance
- 5) Excellent Viscosity Index properties
- 6) Higher flash and fire point (higher auto-ignition temp)

OPERATIONS \ OIL TYPE	PAO-Based Fluid	Mineral Oil
Initial Fill (gal)	60	60
Fluid or Oil Makeup (gal)	15	85
Mineral Oil Changes (9), (gal)	---	540
PAO Fluid Changes (0), (gal)	---	---
Total (gal)	75	625
Cost per (gal), \$	\$20/gal	\$4/gal
Total Cost of Lubricant. \$	1,500.00	2,500.00
Replacement Filters	2	10
Cost of (1) Replacement Filter	\$30.00	\$30.00
Total Filter Cost, \$	\$60.00	\$300.00
Oil Change Labor Cost	\$40.00	\$400.00
<b>TOTAL COST</b>	<b>\$3,200.00</b>	<b>\$6,400.00</b>
Savings from PAO Fluid, \$	\$3,200	---
% Savings with PAO Fluid	50%	---

## Compressor Oil

### Savings

- ✓ Improve overall efficiency
- ✓ Increased stability @ low/high temperature
- ✓ Decreased operating temperature
- ✓ Decreased foaming tendency
- ✓ Decreased lubricant consumption
- ✓ Better wear control
- ✓ Decreased working hours on equipment
- ✓ Decreased global maintenance costs
- ✓ Improved reliability

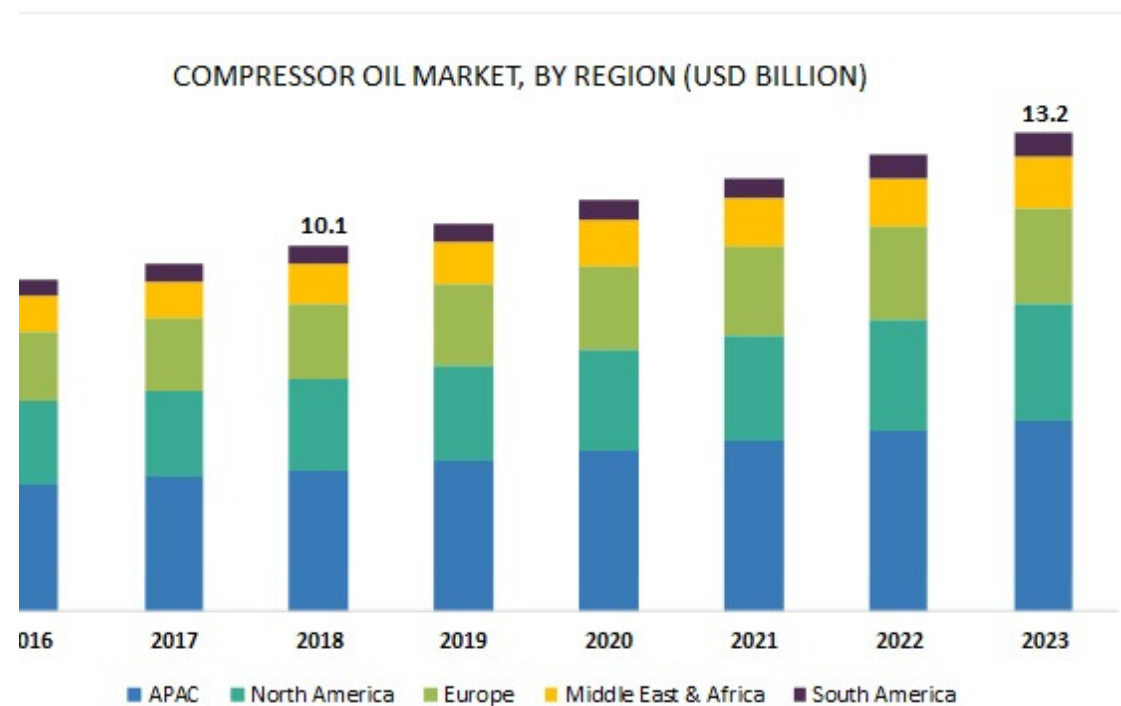
Source: International Lubricants Week Moscow 11 – 14 Nov 2014

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## Compressor Oil Market Trends

A&P is projected to be the largest market due to:

- High growth of the manufacturing industries
- High growth of the construction industries
- High demand from the countries such China and India.



Source: Markets and Markets, Compressor oil market by base oil-Global Forecast 2016 to 2023



# Industrial Gear Oil

*Applications include, but not limited to:*

- |                                            |                                      |
|--------------------------------------------|--------------------------------------|
| ▪ Heavily loaded gear boxes in steel mills | ▪ Power plant gear drives            |
| ▪ Conveyor drives                          | ▪ Rubber mill gear reducers          |
| ▪ Cooling tower fan drives                 | ▪ Chemical plant reactor gear drives |
| ▪ Hoist gear boxes                         | ▪ Cold ambient outdoor gear drives   |
| ▪ Paper mill gear drives                   | ▪ Wire forming gear drives           |



# Industrial Gear Oil

## Typical Industrial Gear Oil Formulations

	ISO VG 220	ISO VG 320
	PAO Formulation	PAO Formulation
Base Oil A	PAO40 >70%	PAO40 60-80%
Base Oil B	PAO8 >10%	PAO100 10-20%
Compatibilizer	Ester 10-20%	Ester 10-20%
Additives	2-5%	2-5%
KV40 (cSt)	223.4	321.0
KV100 (cSt)	26.1	34.8
Viscosity Index	149	153
Pour Point, °C	-39	-42
Brookfield -26°C (mPa•s)	40,000	72,000

Source: <http://gearsolutions.com/features/a-new-class-of-industrial-gear-oil/>



# Industrial Gear Oil

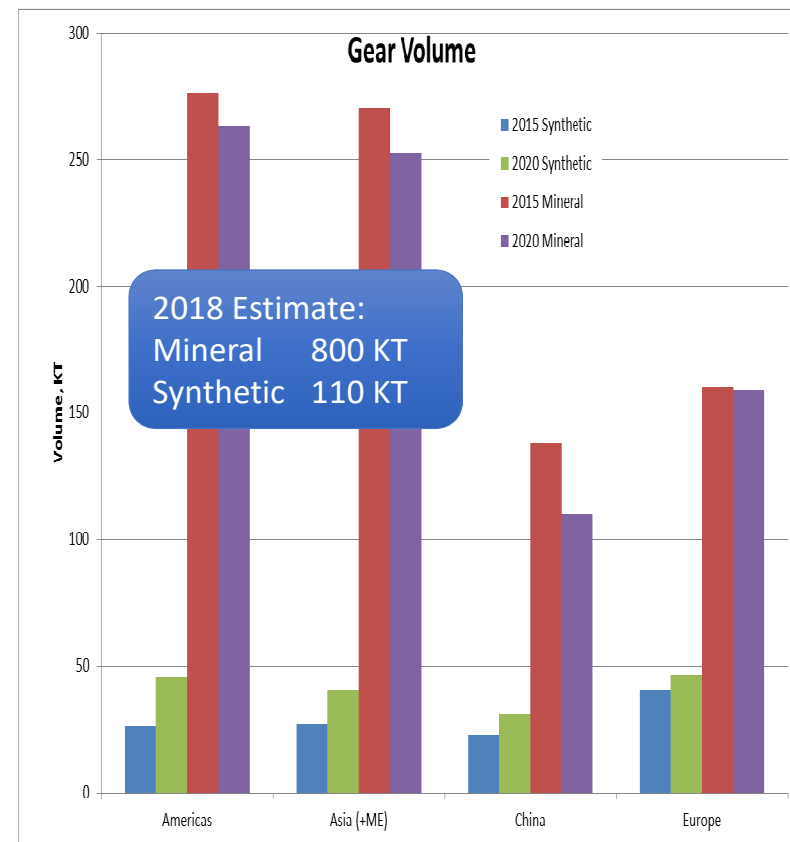
Gear fluid formulations categorized by application:

- Enclosed
- Open

Gear oils fluids find application across a wide range of industrial end-use sectors. These include:

	% Gear in Market	Main Type
Automotive	9	Enclosed
Machinery Manufacturing	7	Enclosed
Electrical/Power Gen	8	Enclosed
Primary Metals	16	Enclosed / Open
Mining	16	Enclosed / Open
Fabricated metals	7	Enclosed
Oil & Gas	4	Enclosed
Textile	3	Enclosed
Chemicals	9	Enclosed
Others	21	Undetermined

Source: Kline 2011



## Industrial Gear Oil Future Challenges

- Smaller gearbox size
  - **Higher** efficiency and **higher** temperature
  - **Smaller** oil tank
- More cost concern
  - **Longer** oil drain interval
  - **Better** filtration requirement
  - Condition monitoring
- Gearbox supplier trend
  - More China gearbox suppliers
  - Industry integration (ZF and Bosch Rexroth)

### Types of Gears





**Wind Turbine**

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# Wind Turbine Oil

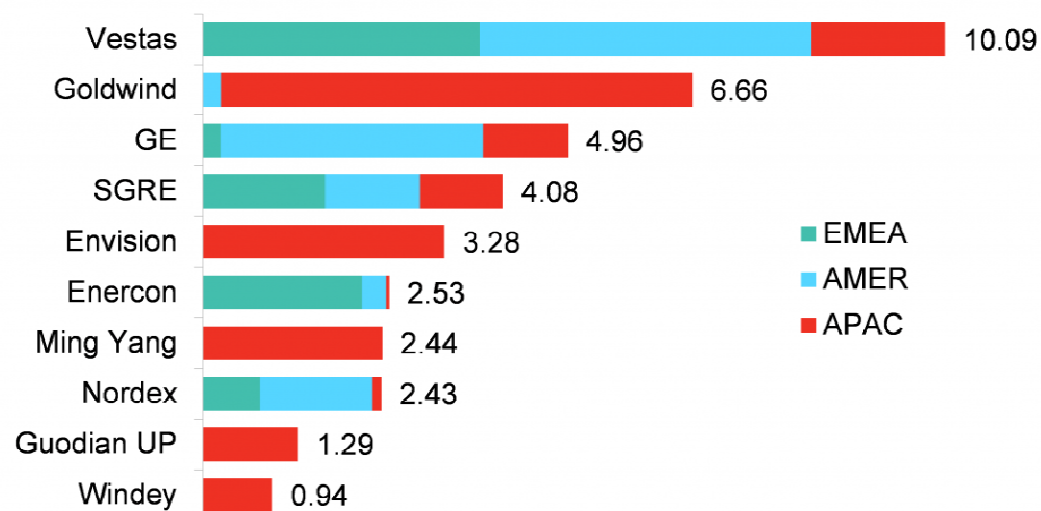
## Typical PAO Containing ISO 320 Wind Turbine Oil

<b>PAO 100</b>	<b>65</b>
<b>PAO 8</b>	<b>25</b>
<b>Ester</b>	<b>10</b>
<b>Additive Package</b>	Not specified
<b>Kinematic Viscosity @ 40°C</b>	<b>318.3</b>
<b>Kinematic Viscosity @ 100°C</b>	<b>35.91</b>
<b>Kinematic Viscosity @ -10°C</b>	<b>10,947</b>
<b>Viscosity Index</b>	<b>160</b>
<b>Pour Point</b>	<b>-48°C</b>
<b>Brookfield Viscosity @-26°C</b>	<b>64,000</b>
<b>KRL Shear Stability 100 Hr</b>	<b>0.7%</b>
<b>FZG 192 HR</b>	<b>1.5</b>

Source: Michael Müller, Evonik Industries analysis

## The Top 10 Global Onshore Wind Turbine Makers of 2018

Gigawatts



Source: BloombergNEF ([BNEF](#))

## PAOs Save Money in Wind Turbines

Typical 1.5 MW Wind turbine operating 7,000 hrs/yr for 20 years;  
Oil Volume = 400L (Larger turbines require more oil)

	Mineral	PAO
Oil Change Interval	14,000 hr	28,000 hr
Oil changes in 20 years	9	4
Oil Consumed	3,600 L	1,600 L
Total Oil Cost	14,000€	13,600 €
	<b>4 € /L</b>	<b>8.5 € /L</b>
Power Loss Cost	189,000€	170,000€
Oil Change Cost (300 €/per)	2,700€	1,200€
Total (with Oil Cost)	206,100€	184,900€
<b>Relative Savings</b>	---	<b>-21,200€</b>



Source: Wilfred Bartz, [www.swisstribology.ch/documents/bartz.pdf](http://www.swisstribology.ch/documents/bartz.pdf)

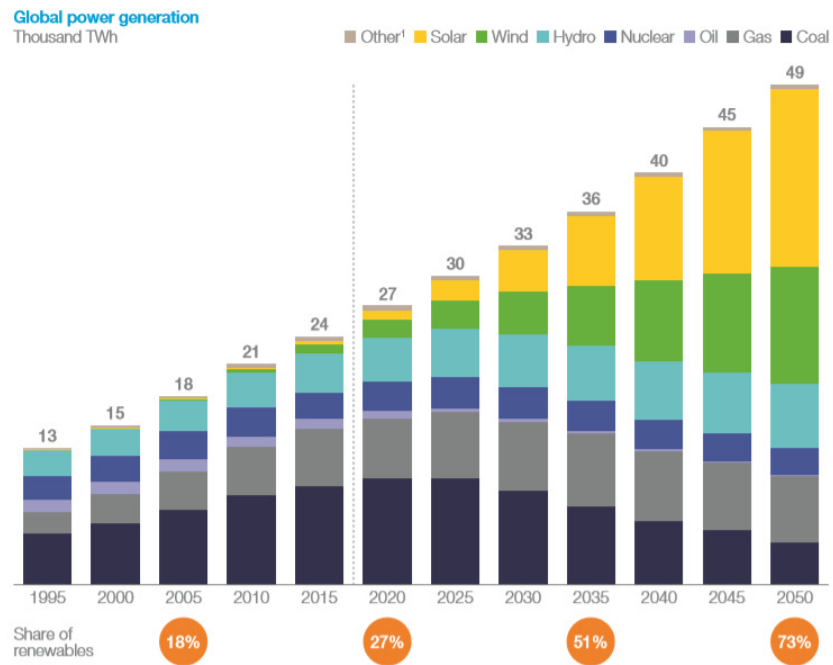
# Wind Turbine Oil

## Wind Turbine Capacity Trends

China accounted for 45% of global growth and its consumption has increased 20-fold in the last 10 years. Wind has accounted for around 50% of renewables generation in the last few years.

Renewable generation accounts for more than 50% of power supply post-2035, a clear trend break from historical fossil fuel-based generation

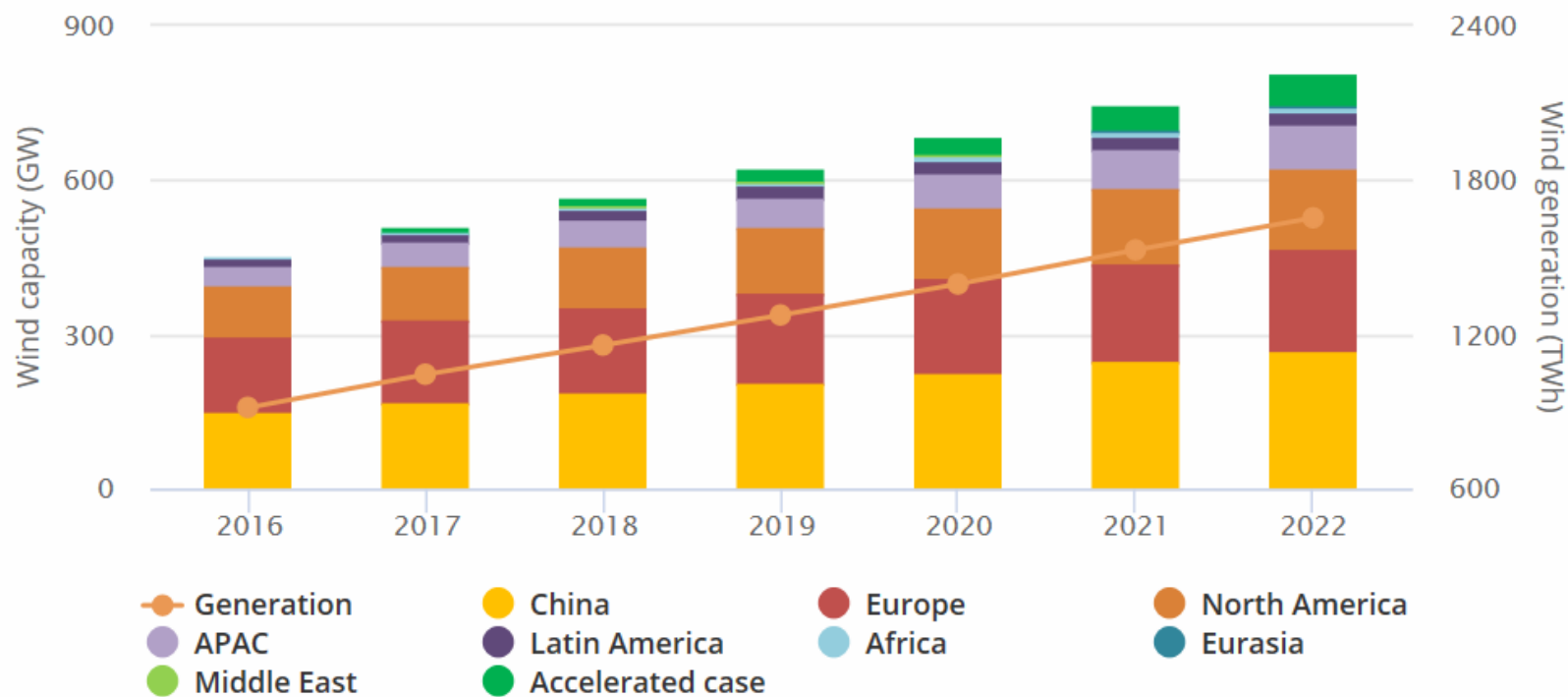
- The role of renewable resources in power generation grows at an accelerated pace. From around 25% today, renewables will grow their share of global generation to around 50% by 2035 and to close to 75% by mid-century
- Coal and oil generation decrease rapidly, partially substituted by renewables, partially by gas-based alternatives with lower cost or lower carbon emissions
- Gas generation often remains to act as a stable base-load and dispatchable capacity provider in a renewable-heavy system but does see a peak around 2035



1 Other includes biomass, geothermal, and marine  
Source: McKinsey Energy Insights' Global Energy Perspective, January 2019

# Wind Turbine Oil

## Onshore wind generation and cumulative capacity by region, 2016-2022

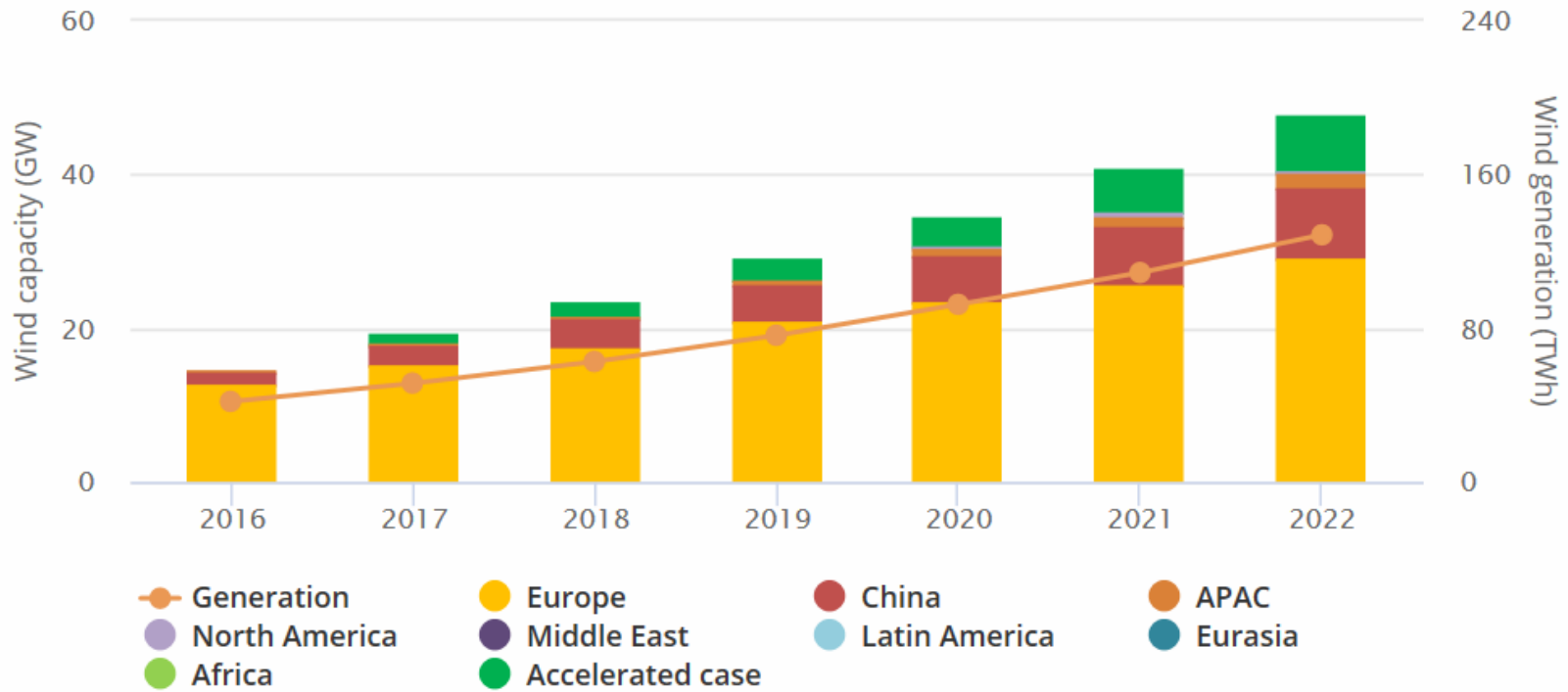


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Source: *Renewables 2018*

# Wind Turbine Oil

## Offshore wind generation and cumulative capacity by region, 2016-2022



Source: *Renewables 2018*

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# Wind Turbine Oil

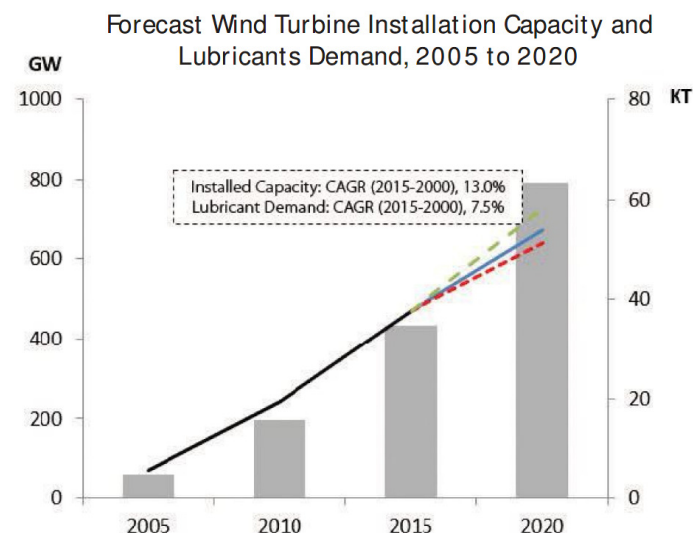
## Wind Turbine Oil Future Trends

In 2015, between 35 and 40 KT of various lubricants were used in wind turbines. Gear lubricants accounted for 70% of the total and those contained about 65% HiVis PAO. Therefore the estimated HiVis PAO requirement in Wind Turbine was 15.9 to 18.2 KT in 2015.

The 2020 Wind Turbine lubricant demand is estimated to be between 51 and 65 KT, requiring about 23.2 to 42.2 KT of HiVis PAO.

2015			
MT	GEAR at 70%	PAO at 80%	HiVis PAO at 65%
35,000	24500	19600	<b>15925</b>
40,000	28000	22400	<b>18200</b>

2020			
MT	GEAR at 70%	PAO at 80%	HiVis PAO at 65%
51,000	35700	28560	<b>23205</b>
65,000	45500	52000	<b>42250</b>



Source: "Positive outlook for wind turbine lubricants", Sushmita Dutta, Kline Consulting as reported in Tribology & Lubrication technology, February 2017

## Future Challenge-WT Gearbox Lubrication Challenges

Industry/ OEM Challenge	Impact to Lubricant	Key Lubricant Formulation Parameter	PAO Advantage
Weight restrictions on gear box: <ul style="list-style-type: none"> <li>•compact design, smaller gear box size</li> <li>•high load handling capability;</li> <li>•case hardening of gears</li> </ul>	Creates environment susceptible to micro-pitting and wear	Micro pitting protection: Gear and bearing protection	Better lubrication and lower friction factor
Demand for extended oil drain intervals: up to 7 years	Demands oil performance retention over time	Oxidative stability/Viscos Foam and air release	Better oxidative stability
Use of fine filtration	Wet oil filterability	Filterability	
Off-shore wind turbines	Creates environment for water contamination; bio-degradeability	Filterability/Water tolerance/Rust and corrosion protection	Better demulsification/foaming and biodegradeability
Changing ambient temperatures and non-permanent operation	Requires stable operation of lubricant: wide ambient temperature range	Viscos/Low Temperature performance	Lower pour point and High Vis index

Source: ExxonMobile Wind Turbine Gear Lubricant 2015

## Ineos New PAO Project

أرامكو السعودية  
Saudi Aramco



INEOS PRESS RELEASE

03 June 2019

This June, INEOS Group announced an agreement to build its first ever petrochemicals complex in the Middle East. The complex will be built in Jubail, Kingdom of Saudi Arabia (KSA) and include world scale plants for: **Linear Alpha Olefin (LAO)** and **Polyalphaolefin (PAO)**. This complex will be located adjacent to a new world-scale cracker, to be constructed by Saudi ARAMCO and TOTAL, which will supply olefin feedstock to the INEOS units.

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