
# Synthetic esters - tunable properties by choosing the right carboxylic acids

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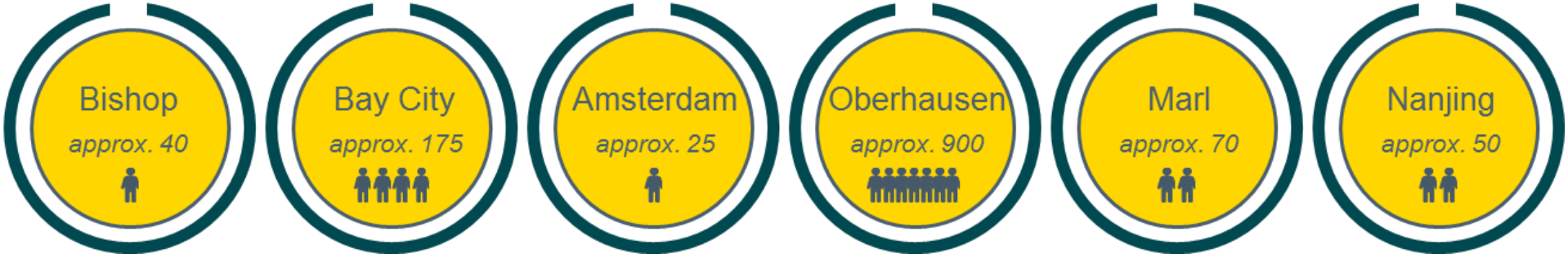
# OXEA in brief

| | |
|---|---|
| **Launch:** | March 1, 2007 |
| **Owner:** | Oman Oil Company (OOC) |
| **Employees:** | approx 1,400 |
| **Sales:** | approx € 1,2 billion |
| **Products:** | Aldehydes, Alcohols, Polyols, Carboxylic Acids, Esters, Amines |

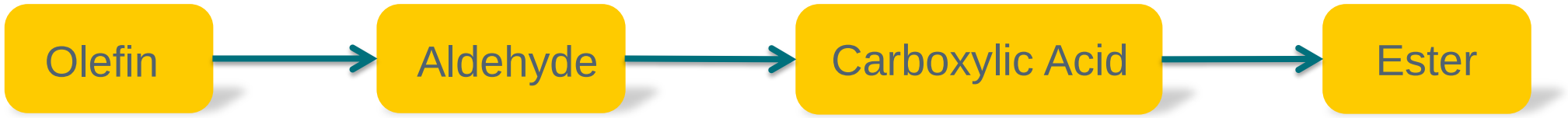
# Global presence


## Production Sites



# Lubricant activities

OXEA is an integrated producer of carboxylic acids and esters




We are supporting the growth of synthetic esters in lubricant applications

**2012**
new ester unit in Oberhausen, Germany

**2013**
new carboxylic acid unit in Oberhausen, Germany

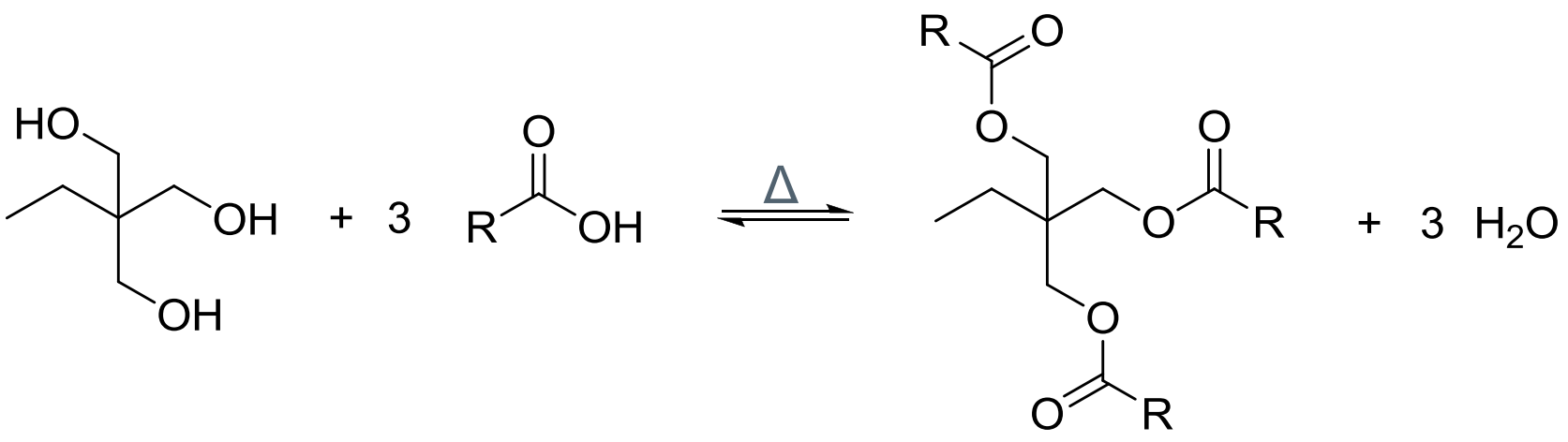
**2014**
new ester plant in Nanjing, China

**2015**
launch of n-Pelargonic Acid HP and Oxlube L9-TMP

...

# Polyolesters – tunable properties for any application

Esterification:



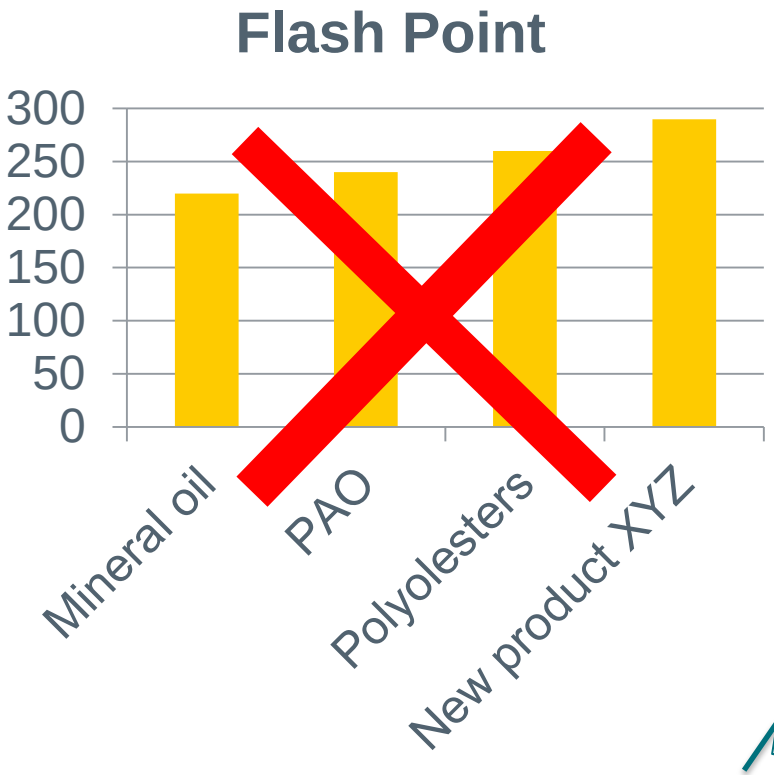

Polyol (e.g. TMP) | Carboxylic acid | Polyolester | Water

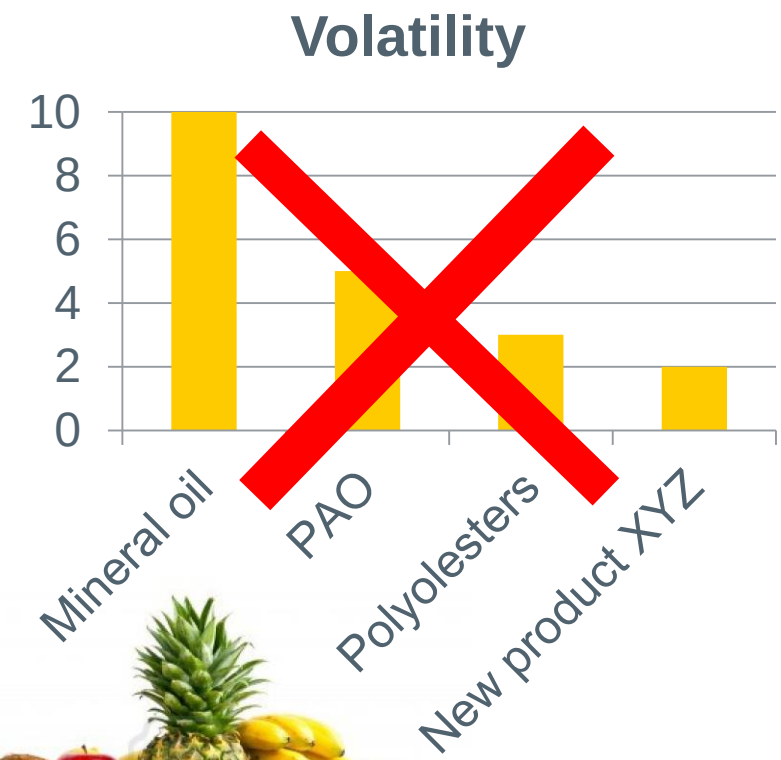
**Due to the variety of possible combinations of polyols and carboxylic acids, polyolesters with tailor-made properties can be produced**

# Polyolesters – tunable properties for any application

A multitude of polyolesters exist, all of them having different properties

So, please avoid oversimplifications:



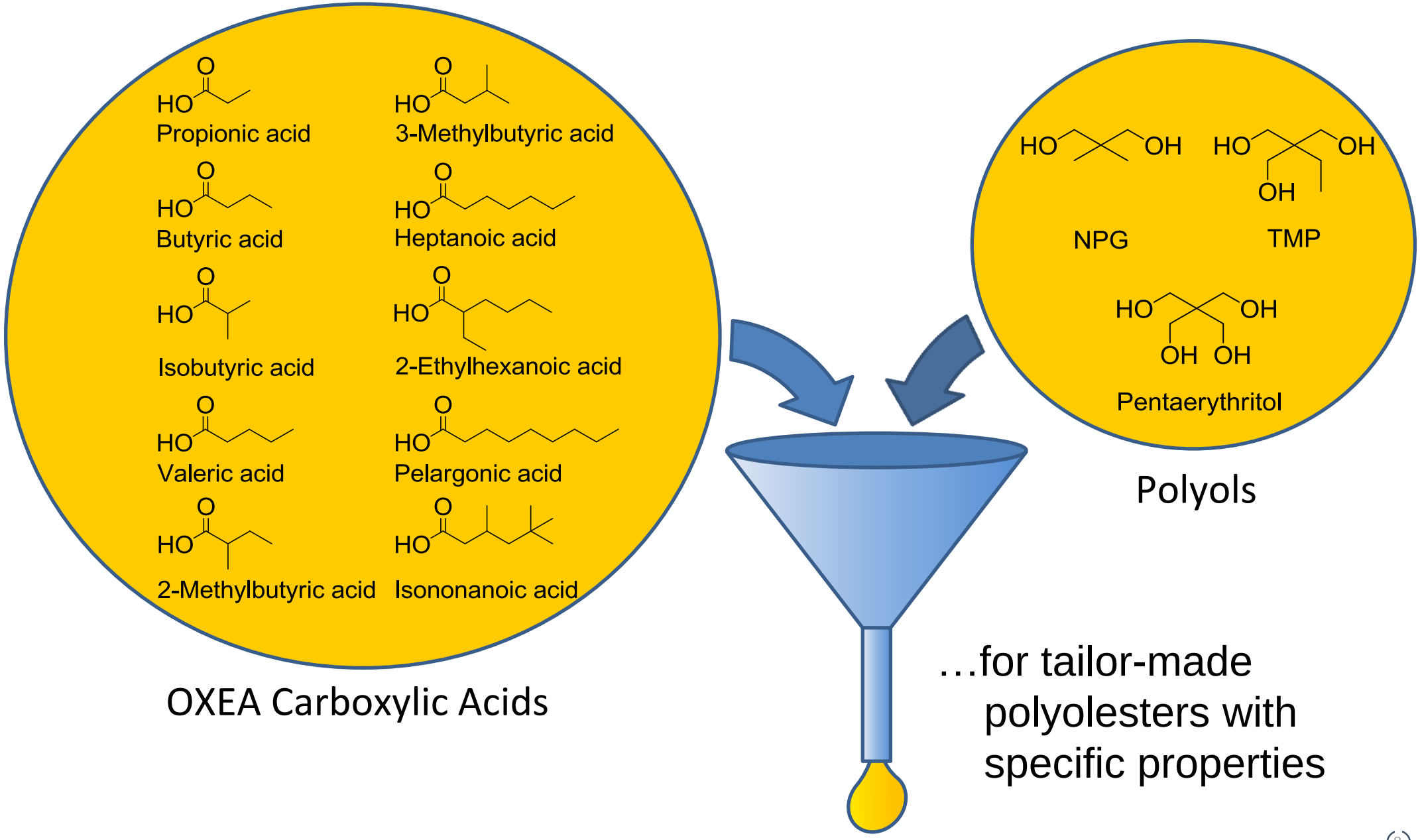

You don‘t compare an 

to 

# An oversimplification

| | Mineral oil | PAO | PAG | Monoester | Diester | Aromatic ester | Polyolester |
|---|---|---|---|---|---|---|---|
| viscosity-temperature | - | | ++ | ++ | ++ | | ++ |
| low temperature fluidity | -- | +++ | ++ | +++ | +++ | - | ++ |
| high temperature stability | -- | + | | -- | + | + | ++ |
| low volatility/evaporation loss | -- | +++ | | - | | +++ | +++ |
| oxidation stability | - | ++ | + | + | + | - | ++ |
| frictional characteristics | - | + | +++ | | +++ | + | ++ |
| biodegradability | -- | - | - | | +++ | -- | ++ |
| hydrolytic stability | +++ | +++ | ++ | -- | - | -- | - |
| additive solubility | +++ | + | | ++ | | ++ | ++ |
| elastomer compatibility | +++ | + | + | -- | -- | -- | - |
| paint/finish compatibility | +++ | +++ | -- | -- | -- | -- | + |
| petroleum compatibility | +++ | | -- | + | + | | + |
| initial cost | +++ | ++ | + | + | + | + | + |

# Choosing the right carboxylic acids…



# Ester properties are depending on the acid used

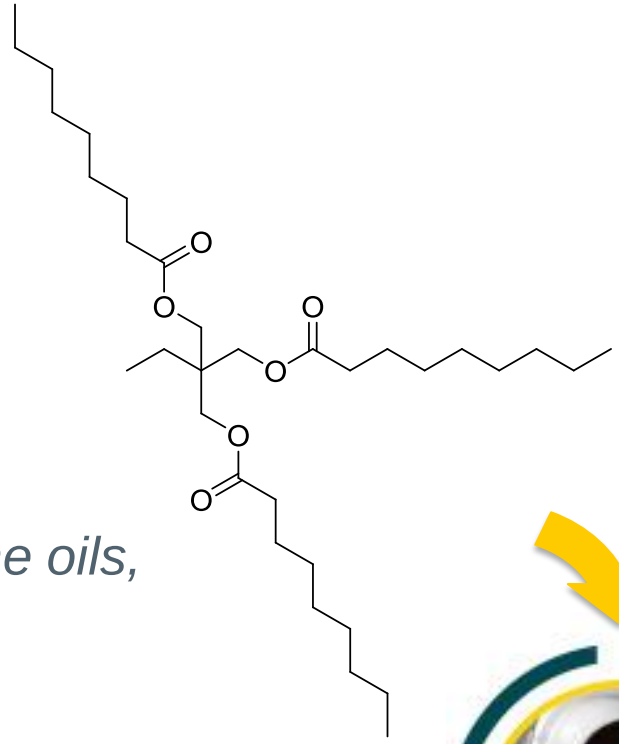
| | Viscosity [mm²/s] | | Viscosity | Density | Pour point | Flash point (COC) |
|---|---|---|---|---|---|---|
| | 40 °C | 100 °C | index | [g/cm³] | [°C] | [°C] |
| **NPG + nC7** | 5,6 | 1,9 | - | 0,9259 | -85 | 190 |
| **NPG + 2-EH** | 7,5 | 2,1 | 65 | 0,9156 | -72 | 180 (CC) |
| **NPG + nC9** | 8,7 | 2,6 | 139 | 0,9131 | -33 | 231 |
| **TMP + nC7** | 13,8 | 3,4 | 122 | 0,9598 | -73 | 254 |
| **TMP + 2-EH** | 25,2 | 4,3 | 55 | 0,9469 | -50 | 237 |
| **TMP + nC9** | 20,0 | 4,5 | 142 | 0,9401 | -45 | 250 |
| **PE + nC5** | 15,9 | 3,6 | 108 | 1,019 | -69 | 250 |
| **PE + 2-MB** | 25,7 | 4,4 | 63 | 1,0151 | -33 | 230 (CC) |
| **PE + nC7** | 22,5 | 4,6 | 121 | 0,9798 | -41 | 263 |
| **PE + 2-EH** | 45,7 | 6,3 | 79 | 0,9636 | -11 | 264 |
| **PE + nC9** | 31,8 | 6,0 | 137 | 0,9544 | 1 | 295 |
| **PE + iC9** | 116,0 | 11,5 | 83 | 0,9523 | -31 | 271 |

**Viscosity:** increasing with chain length and branching, NPG<TMP<PE
**Viscosity index:** increasing with chain length, higher with linear/lower with branched acids
**Density**: decreasing with chain length and branching
**Pour point:** usually increasing with chain length, depending on the branching pattern
**Flash point:** increasing with chain length, NPG<TMP<PE
**Biodegradability**: decreasing with chain length and branching

# OXLUBE L9-TMP

## OXLUBE L9-TMP

an alternative to C8/C10 -TMP ester



- used in diverse lubricant applications:

  *engine oils (2 & 4 stroke), compressor oils, turbine oils, hydraulic fluids, gear oils, chain oils, greases, metalworking fluids, textile spinning fluids*

- high thermal and oxidative stability, low volatility, high flash point, high viscosity index, low pour point, clean burn, good lubricity, readily biodegradable

# Pelargonic acid (nC9) vs. C8/C10 acid

Oxlube L9-TMP is based on pelargonic acid,
which has the same average chain length as the C8/C10 acid mixture

| Properties | | OXEA Pelargonic Acid | OXEA Pelargonic Acid HP | Caprylic/Capric C8C10 acids |
|---|---|---|---|---|
| nC6 acid | % | – | – | ≤ 0.5 |
| nC8 acid | % | – | – | 53 – 63 |
| Total C9 acid | % | min 98.5 | min 99 | – |
| iC9 acid | % | max 3.5 | max 2.0 | – |
| nC9 acid | % | | min 98.0 | |
| nC10 acid | % | – | – | 36 – 47 |
| nC12 acid | % | – | – | ≤ 2.0 |
| Odor | | weak | | slightly unpleasant |
| Appearance | | colorless | | clear pale yellow liquid |
| Color (Pt/Co) | | max 25 | | 40 – 140 |
| Boiling point | °C | 253 | | 237 – 268 |
| Flash point (COC) | °C | 137 | | 135 |
| Melting point | °C | 13 | | 3 – 6 |
| Viscosity @20°C | mPa.s | 8.1 | | 8.8 |
| Density @20°C | g/cm³ | 0.91 | | 0.85 – 0.91 |

OXEA Pelargonic acid shows comparable properties to C8/C10 acid,
even better color and more pleasant odor

# OXLUBE L9-TMP vs. C8/C10-TMP

| Typical properties | Method | Units | Oxlube L9-TMP* (CAS 126-57-8) | C8/C10-TMP* (CAS 91050-89-4) |
|---|---|---|---|---|
| Appearance | Visual | - | clear and bright | clear and bright |
| Water | ASTM E1064/E203 | % | <0.03 | 0,02 |
| Acid number | ASTM D974 | mg KOH/g | <0.05 | 0,02 |
| Colour | ASTM D5386 | Hazen | <100 | <100 |
| Specific gravity @15.6°C | ASTM D4052 | kg/l | 0,94 | 0,94 |
| Viscosity @40°C | ASTM D445 | $mm^2/s$ | 20 | 19 |
| Viscosity @100°C | ASTM D445 | $mm^2/s$ | 4,5 | 4,3 |
| Viscosity index | ASTM D2270 | - | 142 | 137 |
| **Thermal properties** | | | | |
| Noack volatility | CEC L-40-A | weight loss, wt% | **1,73** | 2,42 |
| Volatility @ 205°C (6.5 h) | ASTM D972 | weight loss, wt% | **3,56** | 4,29 |
| Boiling point (50%) | ASTM D2887 | °C | 483 | 475 |
| Flash point (COC) | ASTM D92 | °C | 250 | 257 |
| Pour point | ASTM D5950 | °C | -45 | -48 |
| **Oxidative stability** | | | | |
| RPVOT | ASTM D2272 | minutes | **79** | 63 |
| Dry TOST | ASTM D943 | hours (to 2 mg KOH/g) | **201** | 178 |
| **Biodegradability** | | | | |
| OECD 301B | 28 days | % | **95** | 80 |

*base fluid without any additives

# OXLUBE L9-TMP vs. C8/C10-TMP

**Advantages of L9-TMP**

in comparison to C8/C10-TMP

- ✓ better performance in terms of
  - lower product loss at elevated temperatures
  - higher stability against thermal and oxidative stress
  - better biodegradability
- ✓ comparable properties – one to one replacement possible
- ✓ reliable supply due to dedicated production/synthetic origin of all feedstocks
- ✓ competitive pricing

# Synthetic nC9 vs. natural C8/C10

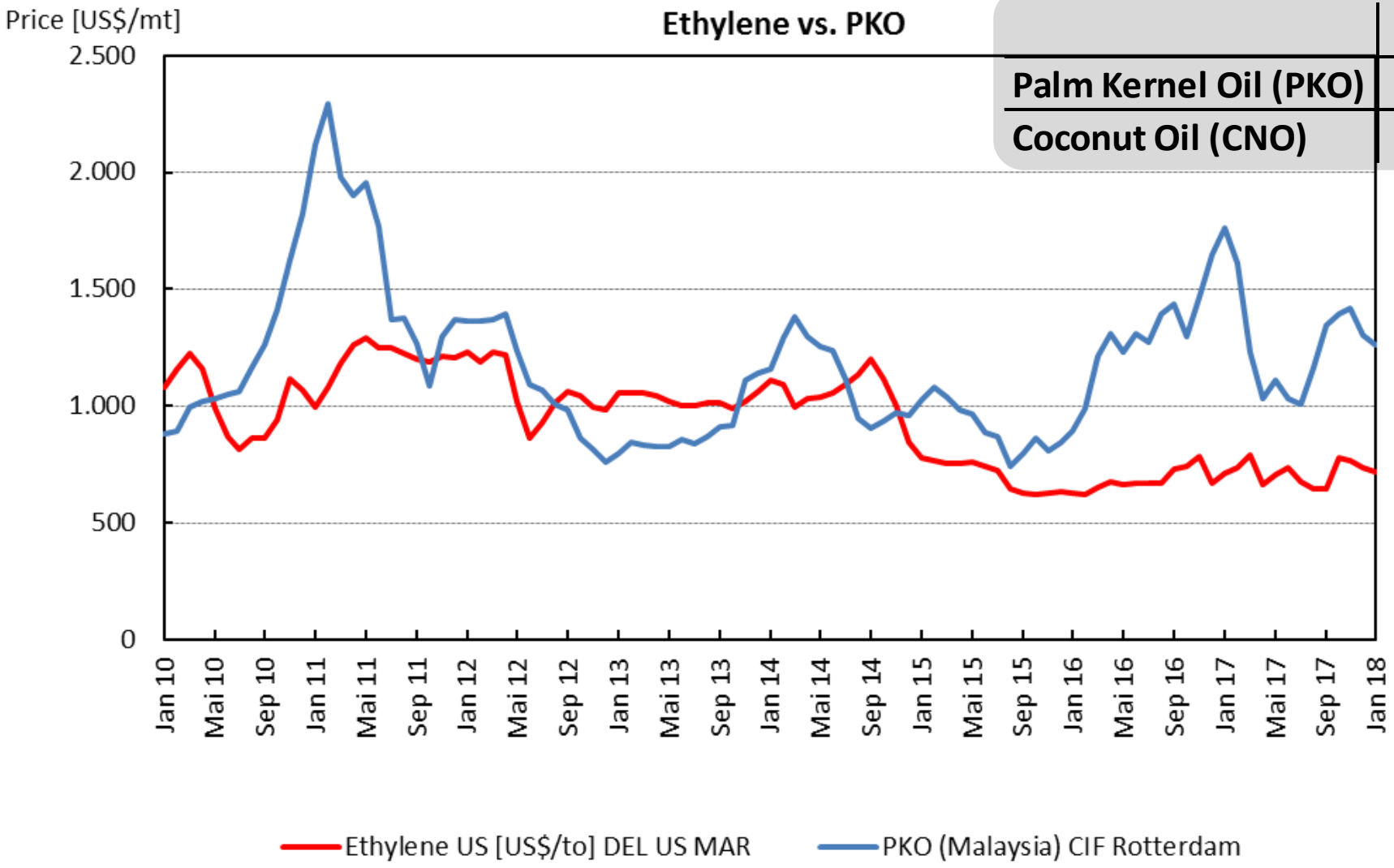
**C8/C10 acid** derived from Palm Kernel Oil (PKO) and Coconut Oil (CNO)

- bio-based
- sustainable?
- supply can get tight (El Niño)
- volatile pricing

**nC9 acid** (OXEA)

- dedicated production using synthetic feedstocks
- reliable supply & pricing
- palm oil free

# Synthetic vs. natural – prices raw materials




| | C8 | C10 |
|---|---|---|
| **Palm Kernel Oil (PKO)** | 3-5% | 3-7% |
| **Coconut Oil (CNO)** | 5-9% | 6-10% |

C8/C10
is a by-product
and limited due to
natural occurrence

→ prices of raw materials (ethylene vs. PKO) in favor of synthetics

# Further nC9 esters for lubricant applications

| Tradename | CAS Nr | Viscosity @ 40°C [$mm^2/s$] | Viscosity @ 100°C [$mm^2/s$] | Viscosity index [$mm^2/s$] | Pour point [°C] | Flash-point (COC) [°C] | Status |
|---|---|---|---|---|---|---|---|
| OXLUBE L9-TMP | 126-57-8 | 20 | 4.5 | 142 | -45 | 250 | Commercial product |
| L9-NPG | 15834-05-6 | 8.7 | 2.6 | 139 | -33 | 231 | Development stage |
| L9-Penta | 14450-05-6 | 31.8 | 6.0 | 137 | 1 | 295 | Development stage |
| L9-glycerol | 126-53-4 | 15.4 | 3.7 | 129 | -10 | 205 (CC) | Development stage |
| OXSOFT L9TM | 35415-27-1 | 50.4 | 7.9 | 125 | -56 | 290 | Commercial product |


integrated producer of carboxylic acids and esters
L9-TMP
high thermal and oxidative stability
tailor-made polyolesters
low volatility
tunable properties
reliable supply
by choosing the right carboxylic acids
readily bio-degradable
OXEA
the oxo people

# Any Questions?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