Base Oil and Wax production

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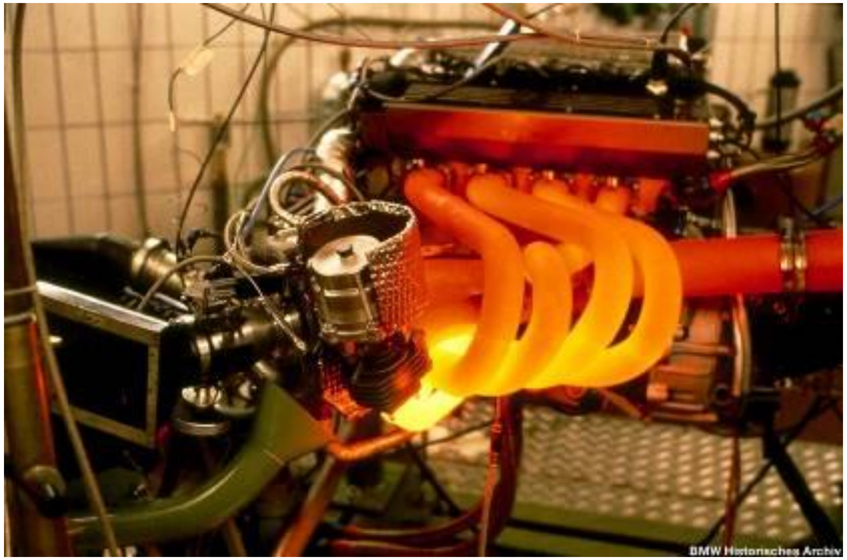
Lubricant Story

- 1400 BC, beef and mutton fat (tallow) being applied to lubricate chariot axles. Very little changed over the next 3000 years except, that the oils sometimes came from more exotic animals such as whales.
- In 1852 petroleum-based oils first became available. They were not widely accepted at first because they did not perform as well as many of the animal-based products. Raw crude did not make very good lubricant.
- But as the demand for automobiles grew, so did the demand for better lubricants.
- Lubricant manufacturers learned soon which crudes made the best lubricants.
- By 1923 the Society of Automotive Engineers classified engine oils by viscosity: light, medium, and heavy. Engine oils contained no additives and had to be replaced every 800-1000 miles.
- In the 1920s more lubrication manufacturers started “processing” their base oils to improve their performance.
- HC technologies were commercialized for lube poruction in late ’50 and dewaxing was in ,’70

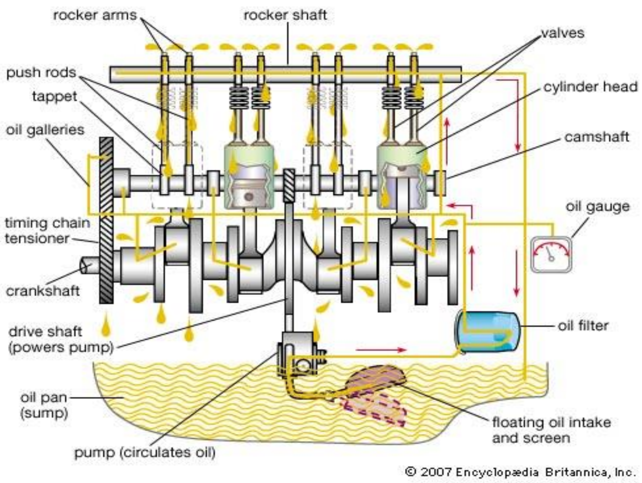
Lubes

- Automotive: engine oils, automatic transmission fluids (ATF’s), gear-oils
- Industrial: machine oils, greases, electrical insulating oils, gas turbine oils
- Pharmacy/cosmetics: white oils, paraffinicum liqudicum
- Provisioning: food grade oils, lining of food containers, cover of food, etc.



Lube Refinery

- Why beneficial to produce base stocks and waxes?
- What are the products and which properties are important?
- Which types of processes?
- Global market and changes



Refinery Outputs

ICIS

Refinery output = global demand

Gasoline 20% - 50%

Distillates (Diesel / HO)
50% - 20%

Jet – Kerosene
10% - 12%

Solvents / Chem
8% – 15%

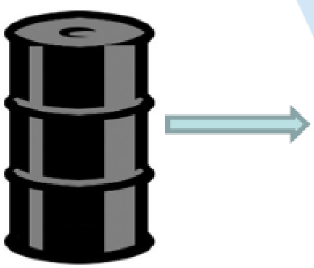
LPG / gases 5% - 10%

Heavy Fuel
Oil 5% - 10%

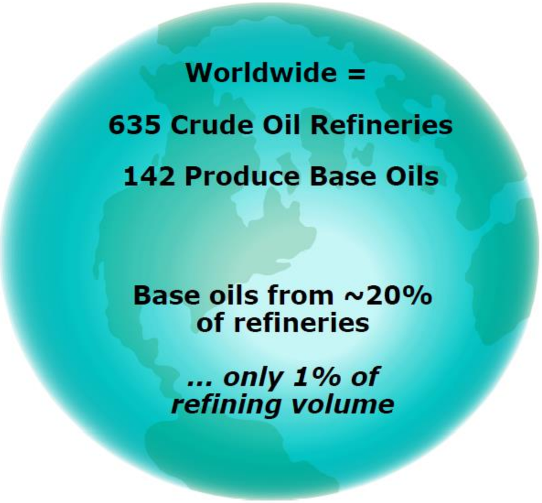
Asphalt
5% - 8%

Base Oils 1%

Other
1%



Sources: IEA, EIA, My Energy

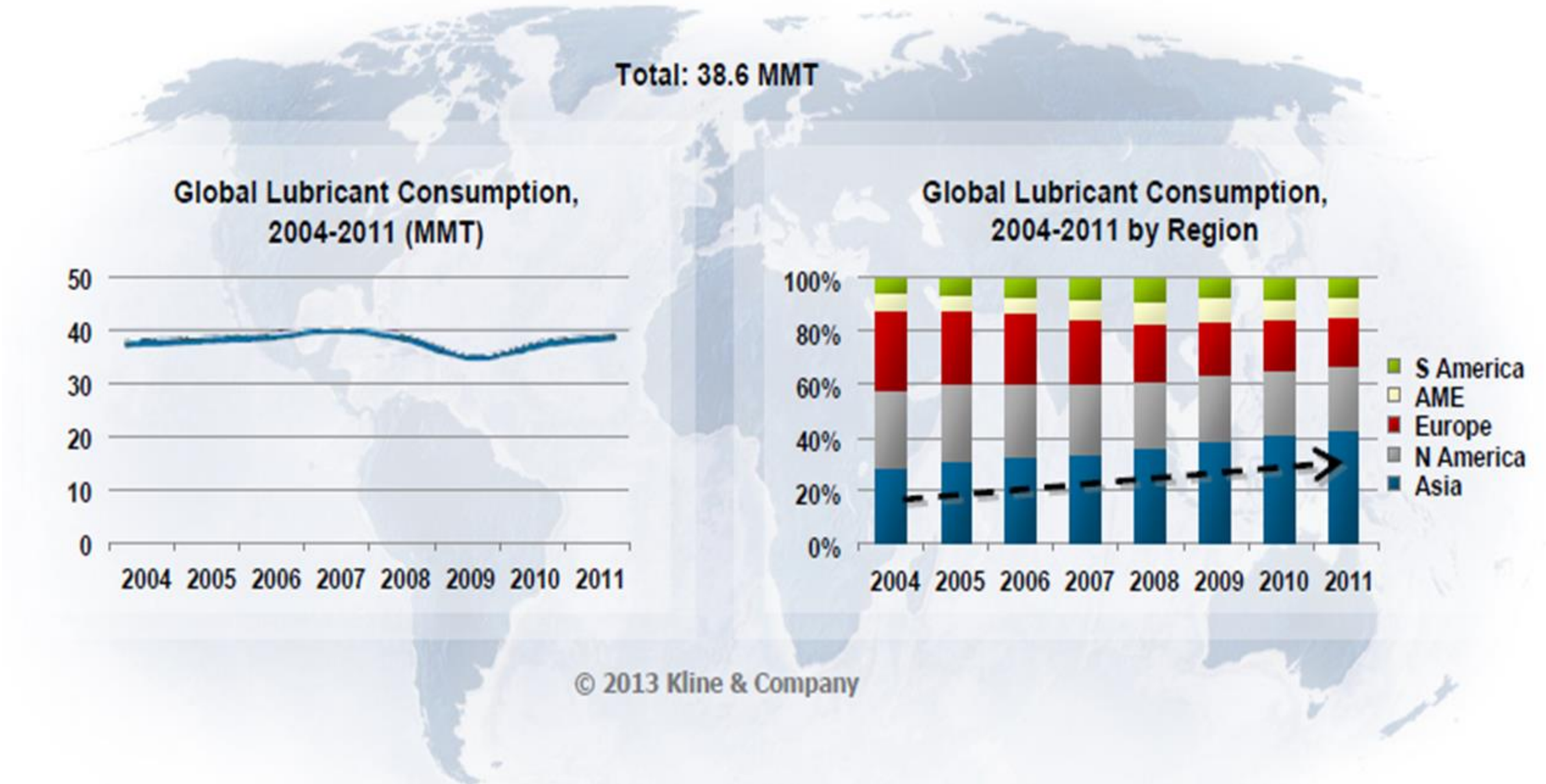


Base oil demand is small compared to transportation fuels and other products

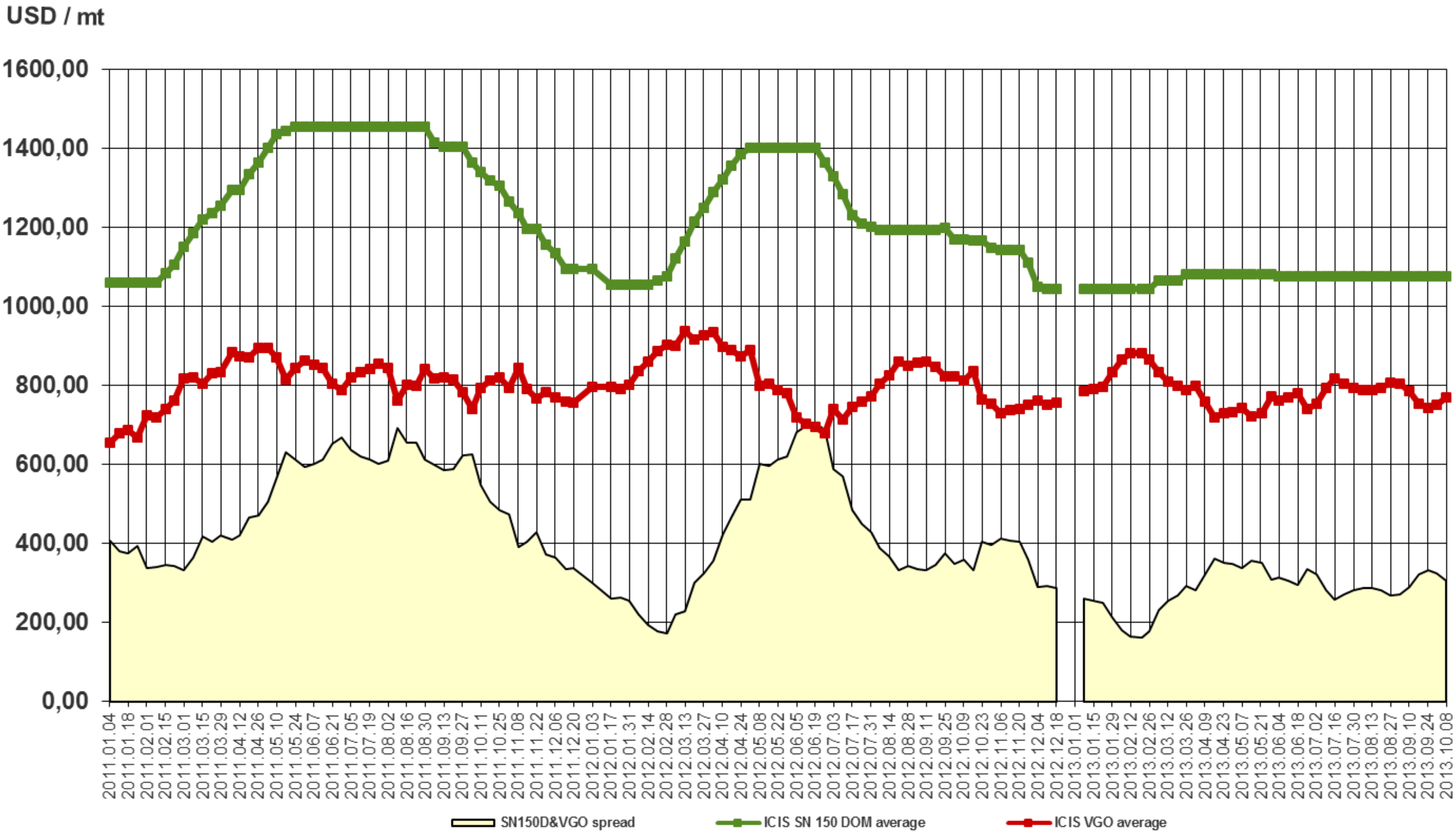
And .. additional refinery capital investment required

Demand & Consumtpion

Global Lubricant Consumption by Region



Prices



USD / mt
1600,00
1400,00
1200,00
1000,00
800,00
600,00
400,00
200,00
0,00
2011.01.04
2011.01.18
2011.02.01
2011.02.15
2011.03.01
2011.03.15
2011.03.29
2011.04.12
2011.04.26
2011.05.10
2011.05.24
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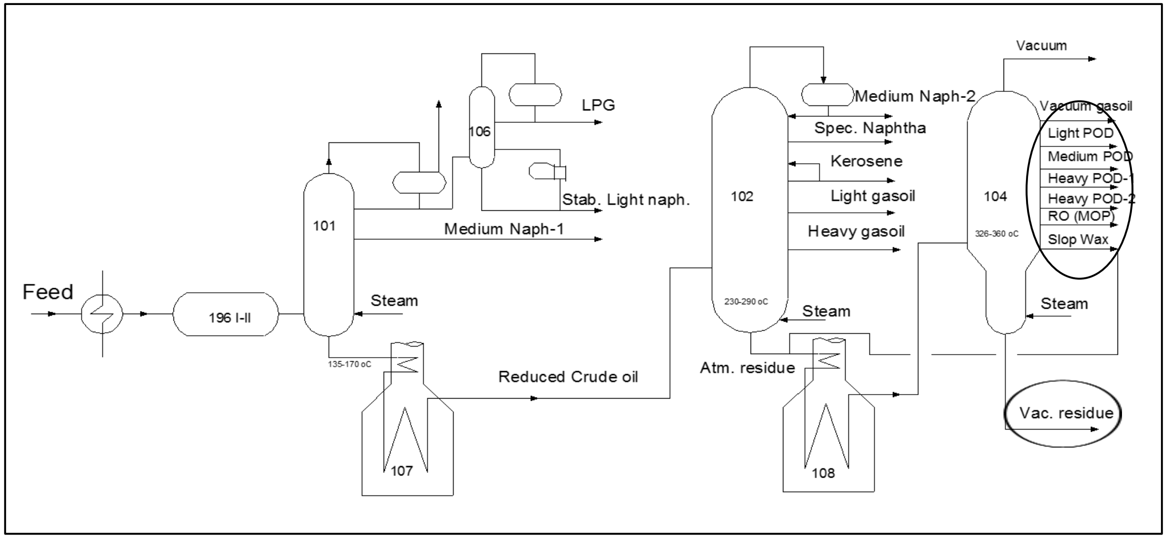
2013.05.07
2013.05.21
2013.06.04
2013.06.18
2013.07.02
2013.07.16
2013.07.30
2013.08.13
2013.08.27
2013.09.10
2013.09.24
2013.10.08
SN150D&VGO spread
ICIS SN 150 DOM average
ICIS VGO average

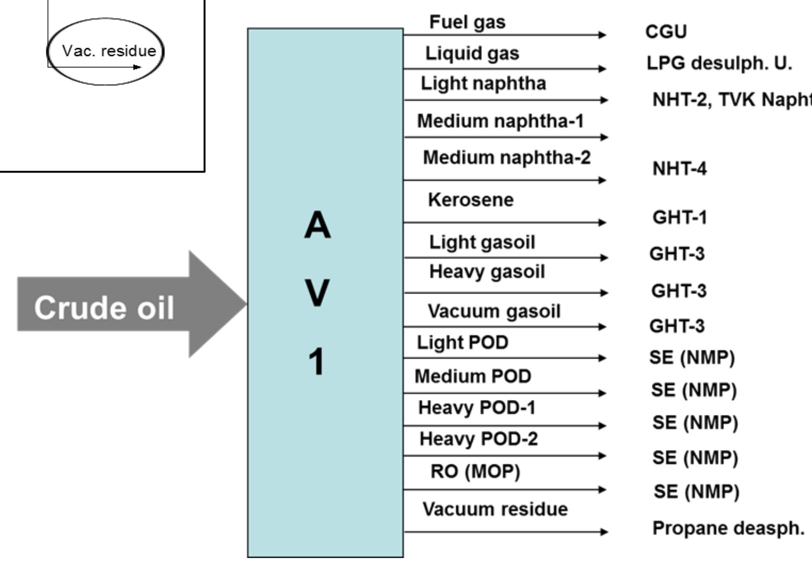
Feedstocks and product portfolio

Feedstocks: Vacuum distillates and residues



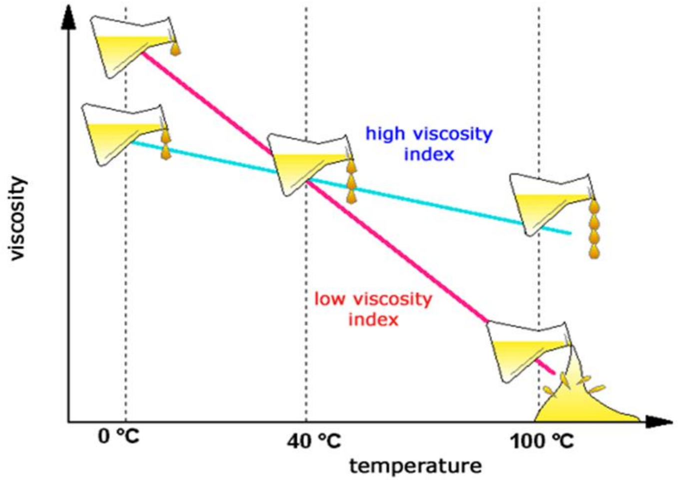
Products and intermediers:

- Base oils
- Waxes
- Paraffins
- Slack-waxes
- Foots oils
- Others: Side products, solvented distillates, dewaxed distillates, etc.



Product properties

Main quality prameters:



Viscosity index

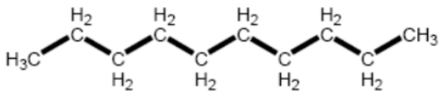
- Viscosity
- Volatily (Noack)
- Viscosity index (VI)
- Pour point: the temperature at which the fluid ceases to pour and is nearly a solid (typically the pour point ranges from -6 to -24°C for heavy to light neutrals)
- Cloud point: the temperature at which the first wax crystals appear
- Saturates, aromatics, naphthenes content
- Color (change appearance in presence of light)
- Stability (change appearance in presence of heat)
- Melting point (waxes)

Base Oils API Groups

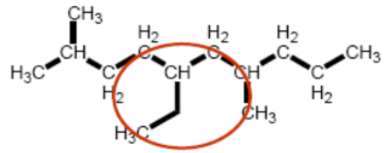
API Group	% saturates	% sulfur	VI
I	< 90 % sats ***and/or***	> 0.03% S	≥ 80 and <120
II	≥ 90 % sats ***and***	≤ 0.03% S	≥ 80 and <120
III	≥ 90 % sats ***and***	≤ 0.03% S	≥ 120
IV	Poly-alpha-olefins (PAO)		
V	Basestocks not included in Groups I – IV		

Source: API 1509 Appendix E

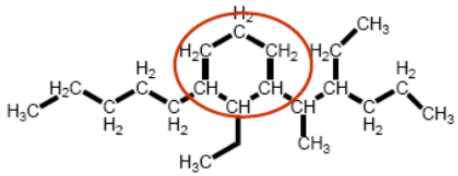
Feedstock composition



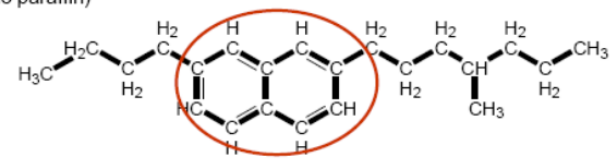
n-Paraffin (straight chain)

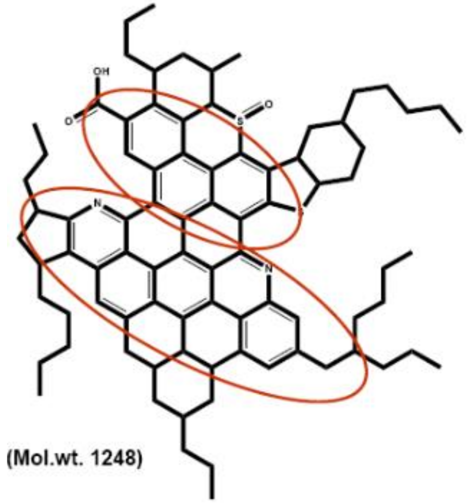


iso-Paraffin (branched chain)

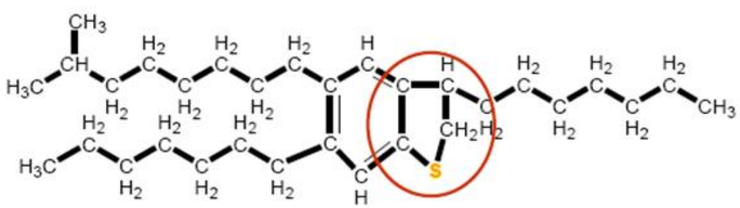


Naphthene (cyclo paraffin)

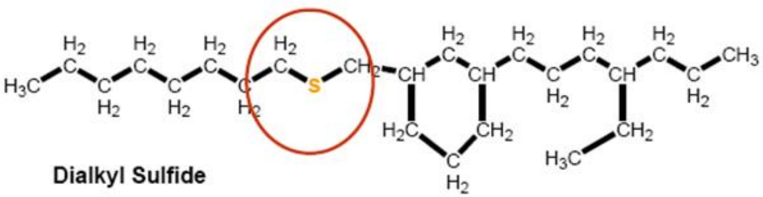




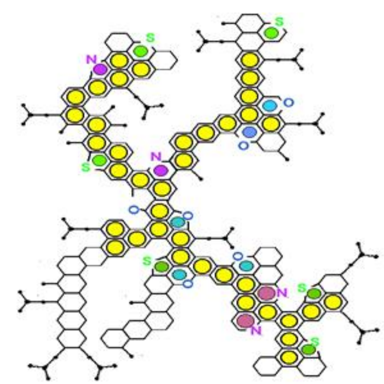
(Mol.wt. 1248)



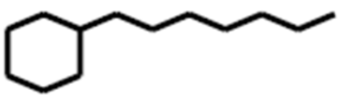
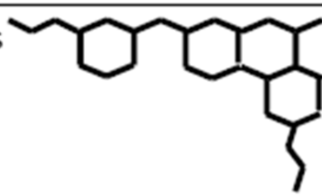
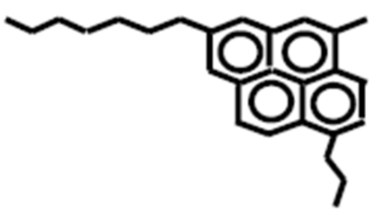
Benzothiophene (sulfur hetrocyclic)



Dialkyl Sulfide



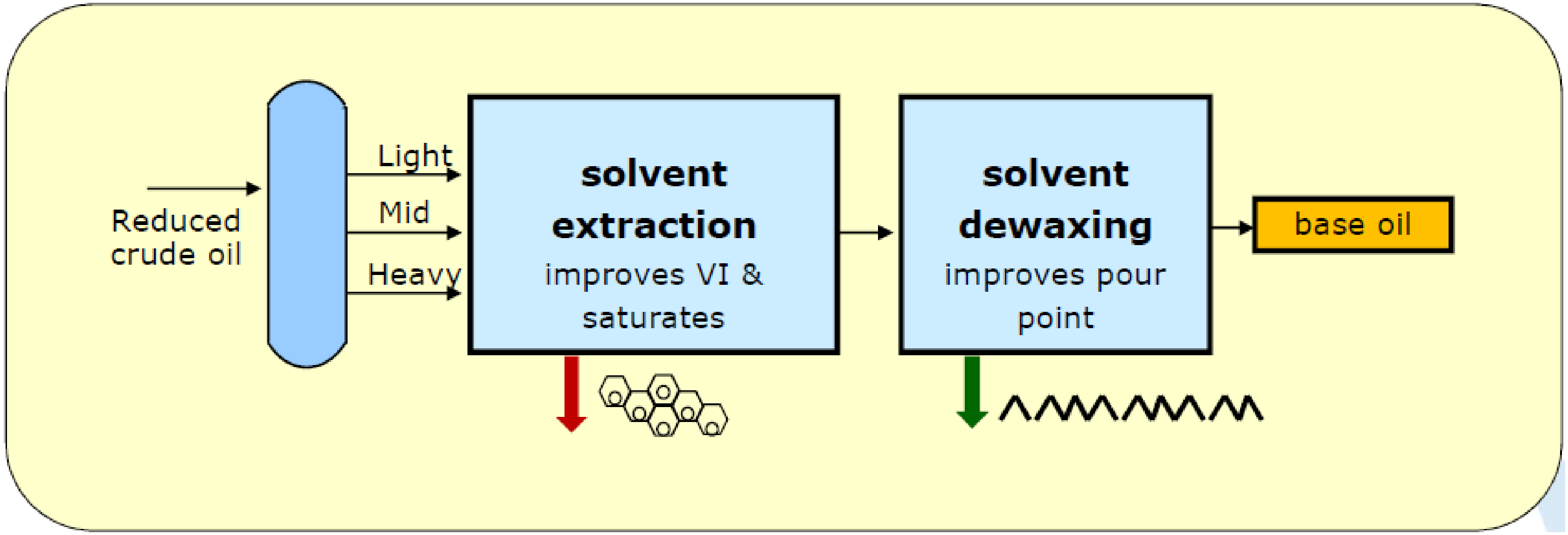
Effect of molecular types

Designation	Viscosity Index	Pour Point	Resistance to Oxidation	Value as Base Oil
n-paraffins 	✓✓✓✓	✓	✓✓✓✓	✓✓✓
iso-paraffins 	✓✓✓	✓✓✓	✓✓✓✓	✓✓✓✓
Mono-naphthenes 	✓✓	✓✓	✓✓✓	✓✓✓
Poly-naphthenes 	✓✓	✓✓✓	✓✓	Nil
Aromatics 	✓	✓✓✓	✓	Nil

Solvent processes

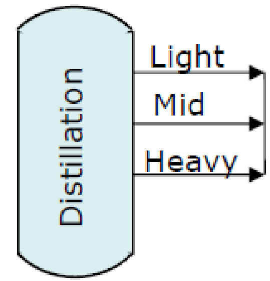
<u>Main three process steps</u>

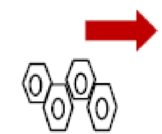
- Crude distillation to Light-, Medium- and Heavy feed fractions
- Remove the unwanted aromatics – solvent extraction
- Remove paraffins and waxes – solvent dewaxing



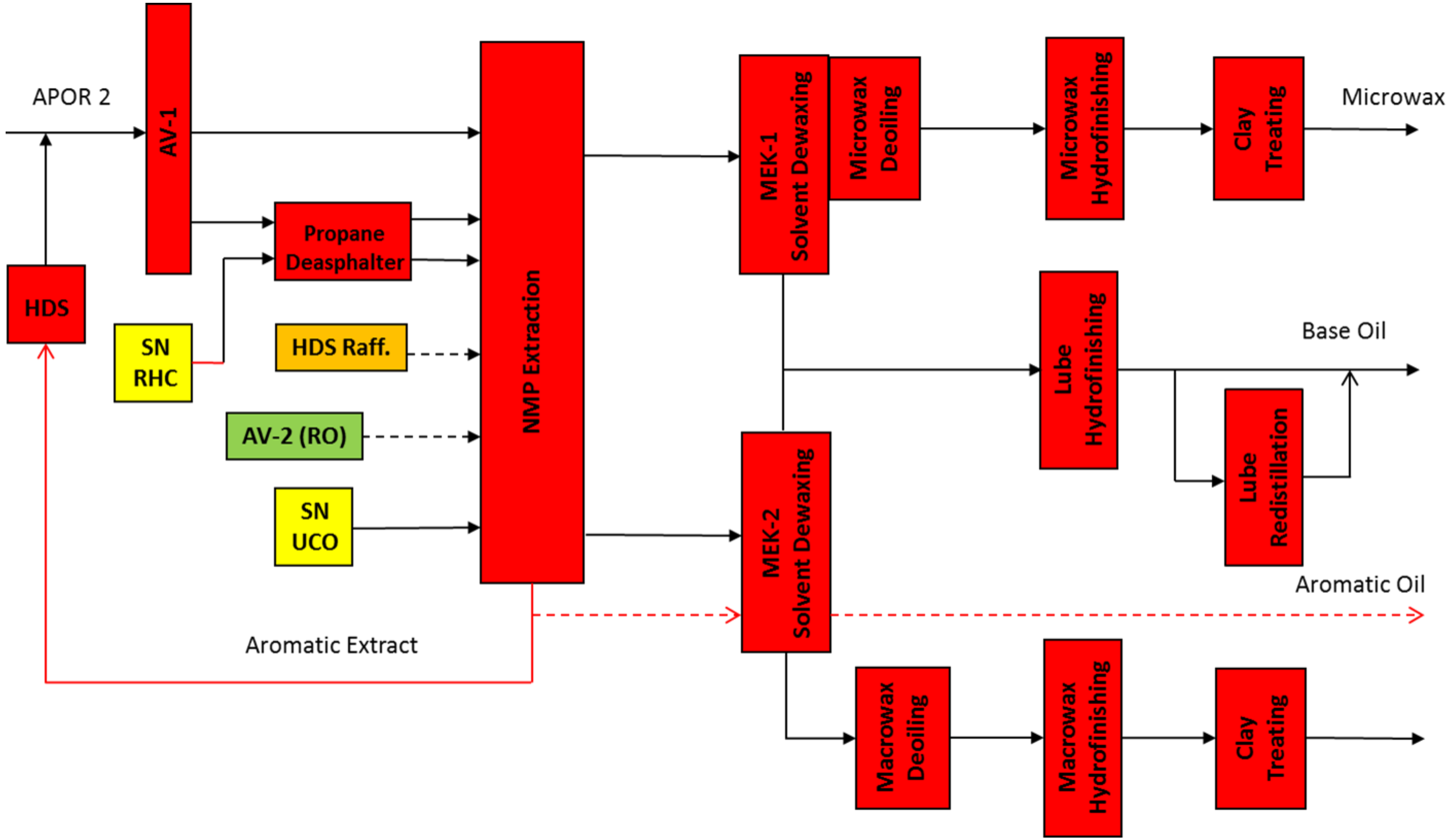
Quality parameter controls

Property	Where controlled
Viscosity	Crude distillation isolates heavy molecules and creates primary viscosity grades
VI (higher is better)	Solvent extraction (aromatics removal) + VI increases as aromatics are removed
Saturates (higher is better)	Solvent extraction (aromatics removal) + Saturates increase as aromatics are removed
Pour Point (lower is better)	Solvent dewaxing (wax removal) + Pour point decreases as wax is removed



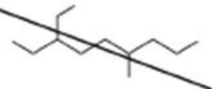
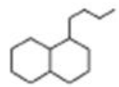
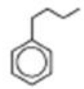
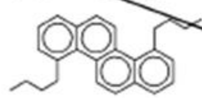


Base Oil production in Danube Refinery



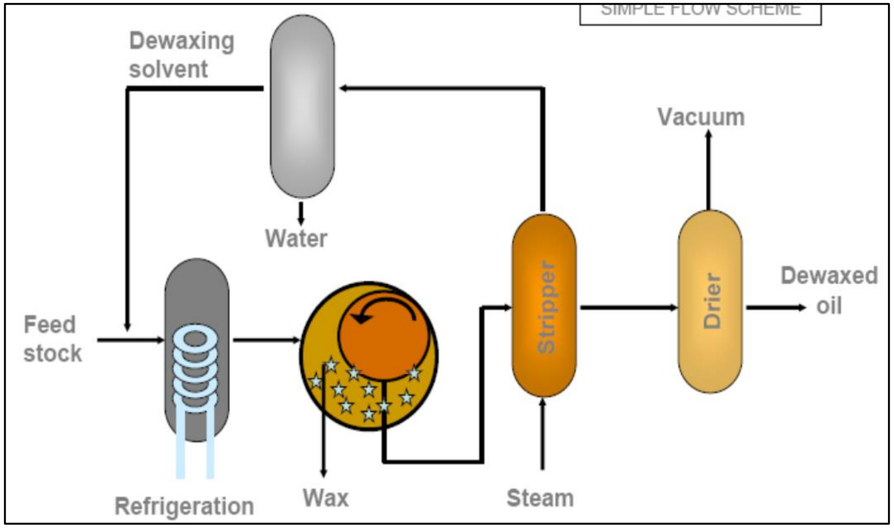
Molecules and processes

EXTRACTION ↑

Molecule	Structure	Base Stock Quality Affected	Process Involved
N-Paraffin		High Pour, VI No S and CCR	Dewaxing
I-Paraffin		High VI and Sats Medium Pour	
2-Ring Naphthene		Medium VI, Low Pour, High Acids	Extraction, Hydrofinishing
1-Ring Aromatic		Medium to High VI	Extraction
Multi-Ring Naphthene		Low VI, Low Pour, High Acids	Extraction, Hydrofinishing
Multi-Ring Aromatic		Low VI, Low Pour	Extraction
Organic Sulfur		Good Stability Antioxidant	Hydrofinishing
Organic Nitrogen		Poor Stability	Hydrofinishing
Aliphatic Sulfur and Nitrogen	R-S R-N	Removed by Hydrofinishing	Hydrofinishing
Asphaltenes	Condensed Multi-Rings	High CCR Poor Color	Distillation, Deasphalting

DEWAXING ↓

Process solvent and ratios



Solvent Dewaxing

Solvent Deasphalting

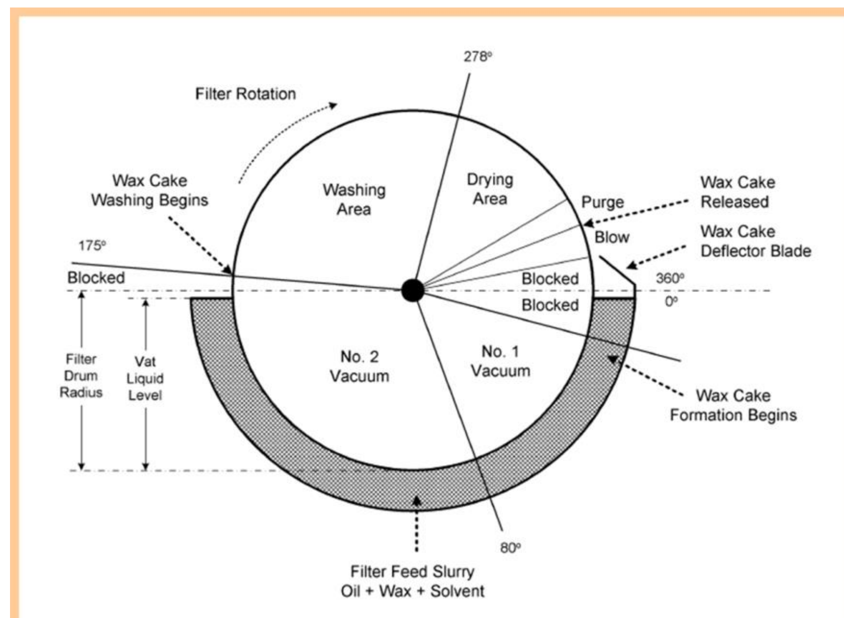
Solvents: **Propane** to Heptane $\mathbf{C_3}$ - C_7
Typical solvent ratio (C_3 case): 1:3,4-3,6 t/t

Solvent Treating (Aromatic removal)

Solvents: Furfural, Phenol,
NMP (N-methyl pyrolidone)
Typical solvent ratio (NMP case): 1:1,75-2,25 t/t

Solvent Dewaxing and Deoiling

Solvents: **MEK, Toluene,** Acetone
Typical solvent ratio (MEK-T): 1:3 - 1:5 t/t
Solvent Composition: MEK 40-45%, T: 55-60%



Wax Filtering

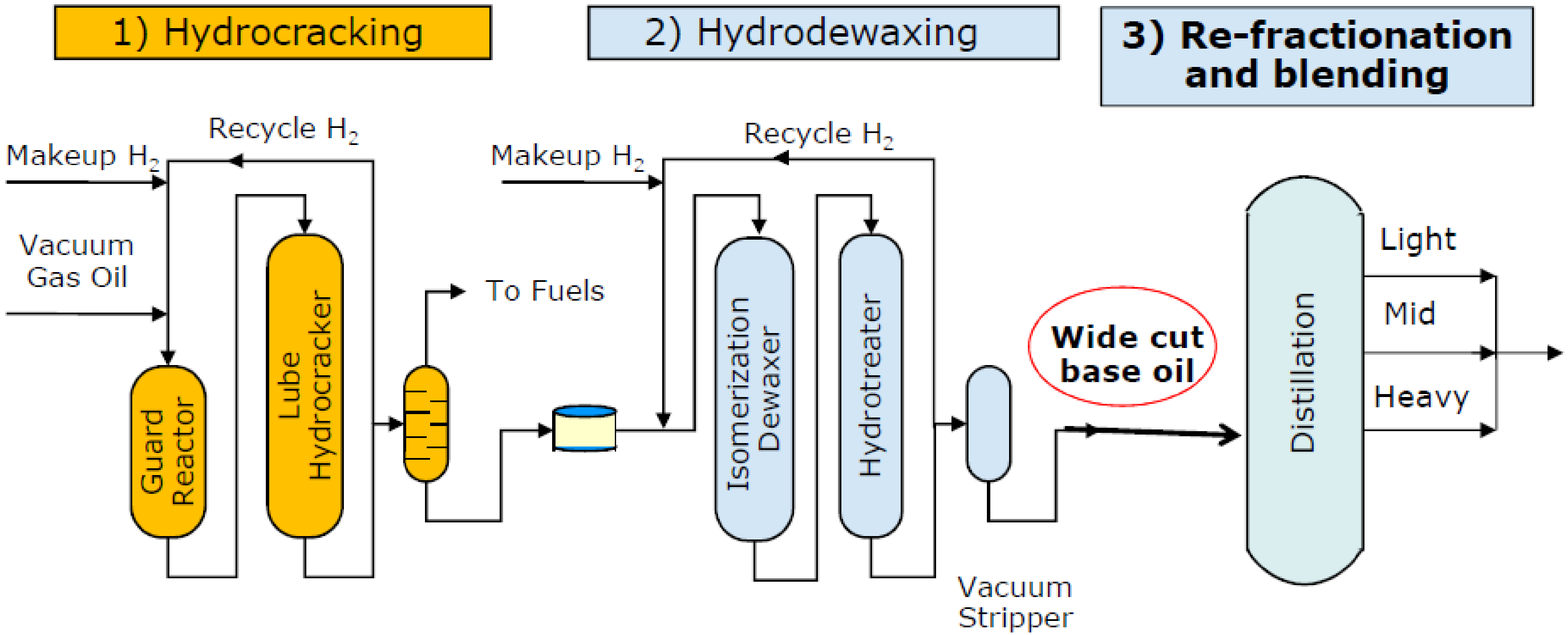
Process types and steps

- Solvent processes
  - Vacuum distillation
  - Solvent Deasphalting
  - Solvent Extraction
  - Solvent Dewaxing
  - Solvent Deoiling
  - Hydrotreating
  - Clay treating

- Catalytic processes
  - Vacuum distillation
  - Base Oil Hydrocracking
  - Cat. Dewaxing / Isodewaxing
  - Hydrotreating

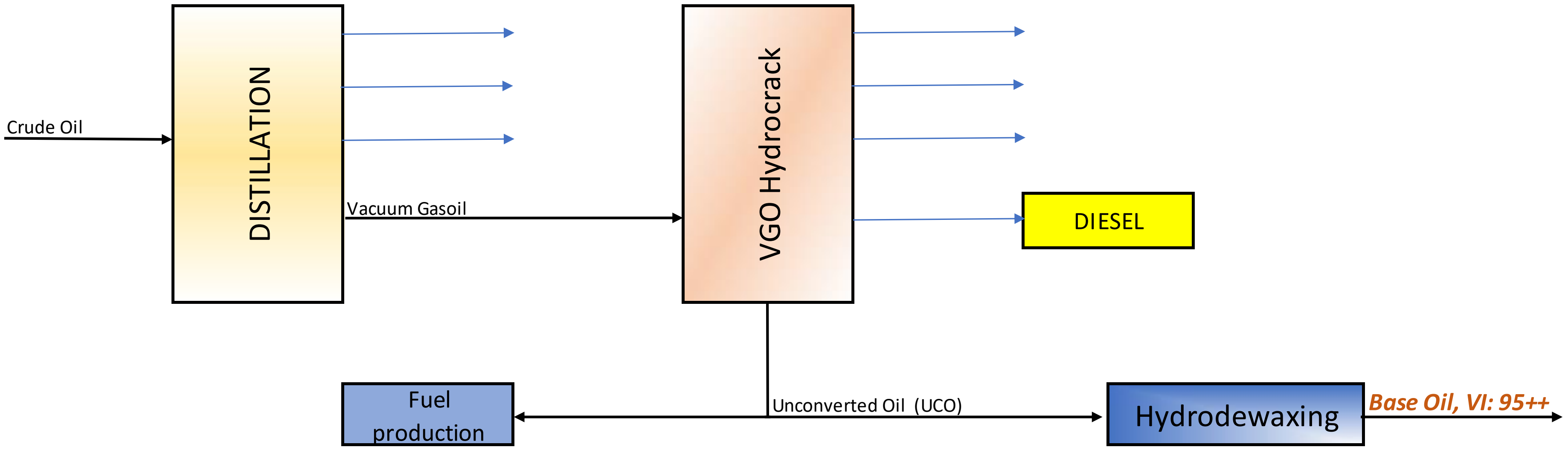
Base Oil Hydrocracking & Isodewaxing

- Catalytic Lube Hydrocracking & Catalytic Dewaxing



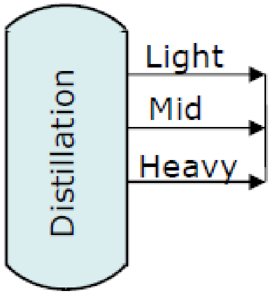
Group III production on HCU base

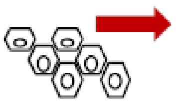
- Base case: VGO Hydrocracker unit (HCU) exists for Diesel production
- Unconverted Oil (HCU Residue) is applicable for Base Oil Production
- Only a Hydrodewaxing unit is needed, Lube Hydrocracker unit is not needed



Catalytic quality parameter controls

Property	**Process where controlled**
Viscosity	Crude distillation and back-end re-distillation after hydrocracking / hydrodewaxing
VI	Hydrocracking + VI increases as aromatics are removed
Saturates	Hydrocracking + Sats increase as aromatics are removed
Pour Point	Hydrodewaxing + Pour point decreases as wax is removed



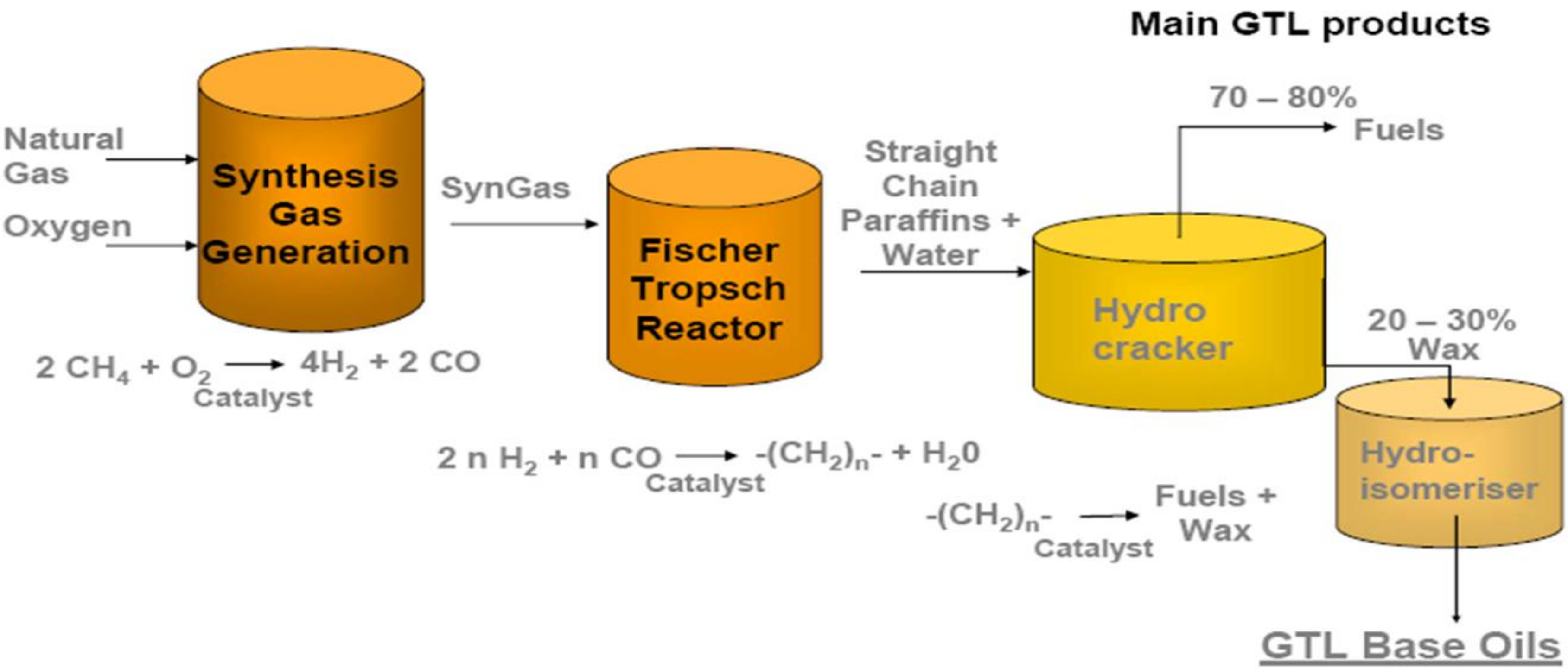


Aromatics

Wax

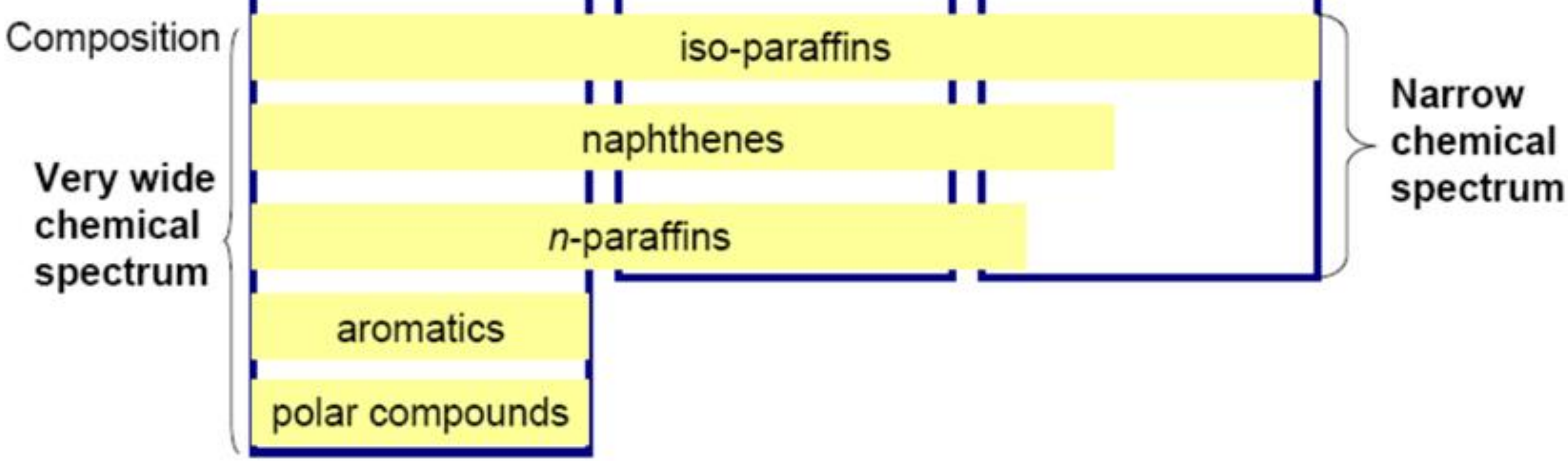
Group III+ production on GTL process

- Fischer-Tropsch process base
- F-T HCs products are a white waxy crude for upgrading
- Group III+ quality Base Oils can be produced next to the fuels



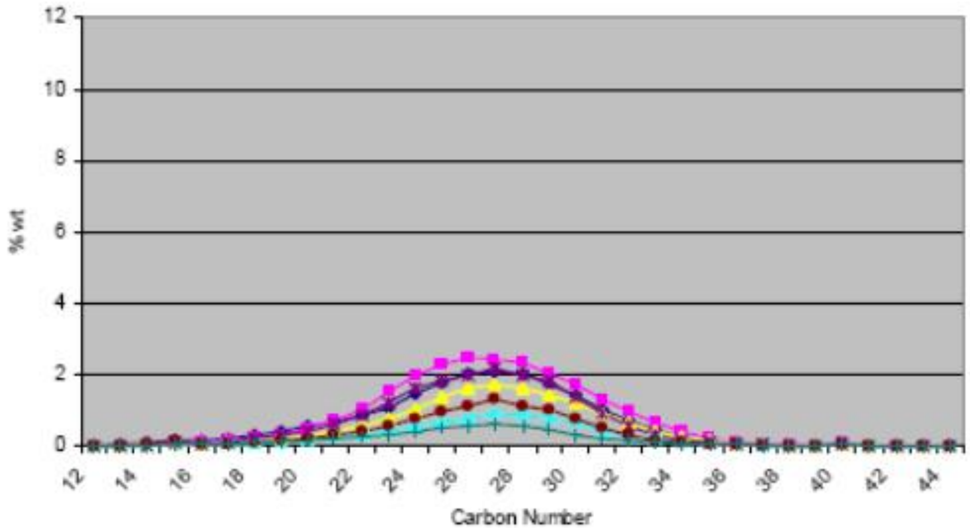
Typical API Group composition

Category	Group I	Group II	Group III
VI	$80 \le VI < 120$	$80 \le VI < 120$	$VI \ge 120$
Saturates	$< 90\%$	$\ge 90\%$	$\ge 90\%$
Sulphur	$> 0.03\%$	$\le 0.03\%$	$\le 0.03\%$

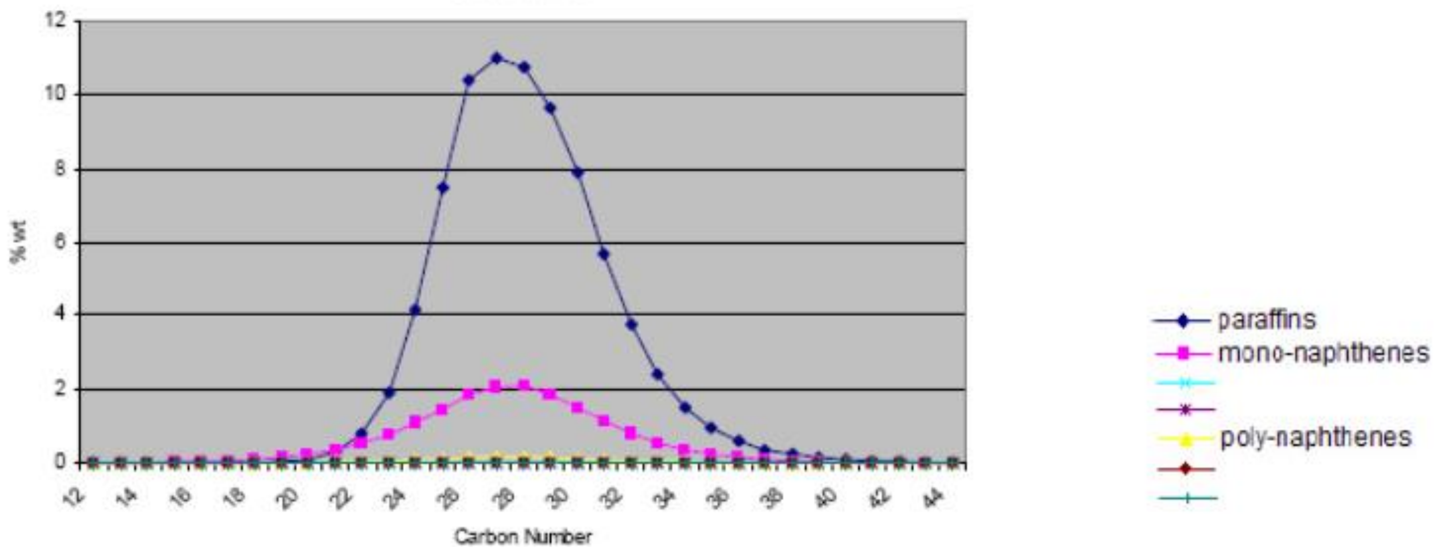


Composition differences

Group I



Group III



API Groups - What's better?

Same Labels, New Perceptions Regarding What's "Better"?

Fine oxidation stability (95 VI)

Better oxidation stability (higher saturates, higher VI)

Naphthenics

Group I

Group II

Group III

Group III+

PAO

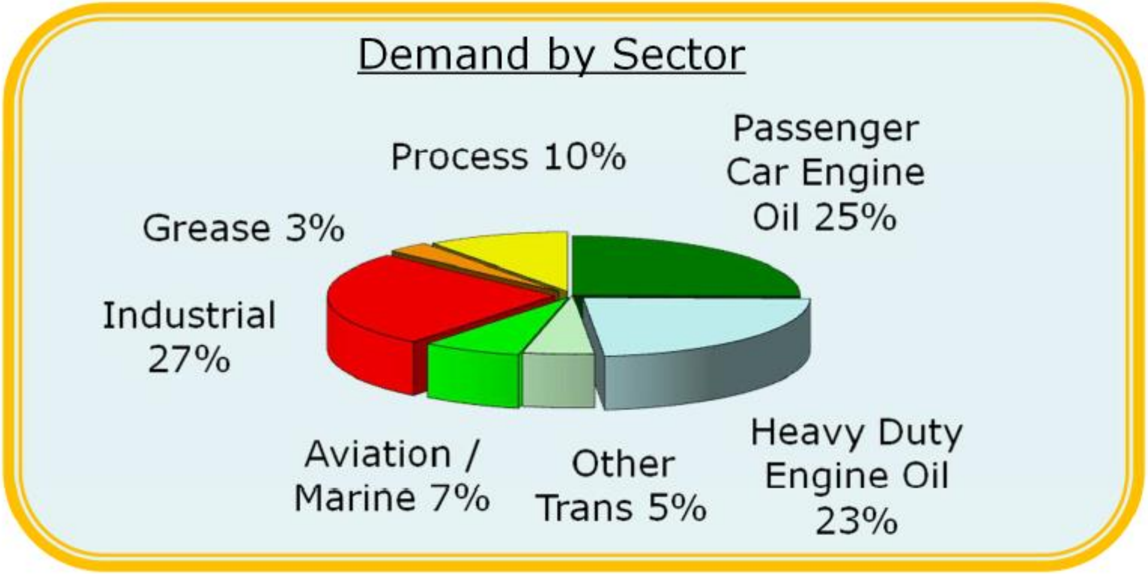
Better solvency

Higher viscosity grades

Poor solvency (absence of aromatics, naphthenes)

Lubricant market

- **Transportation-related lubrication is largest market at around 60% of global applications**



- **Industrial / grease applications are ~ 30%**
- **Non-lubricating applications ("process oils") are ~ 10%**

Sources: My Energy Databases, Fuchs Lubricants, Kline & Company

www.icis.com

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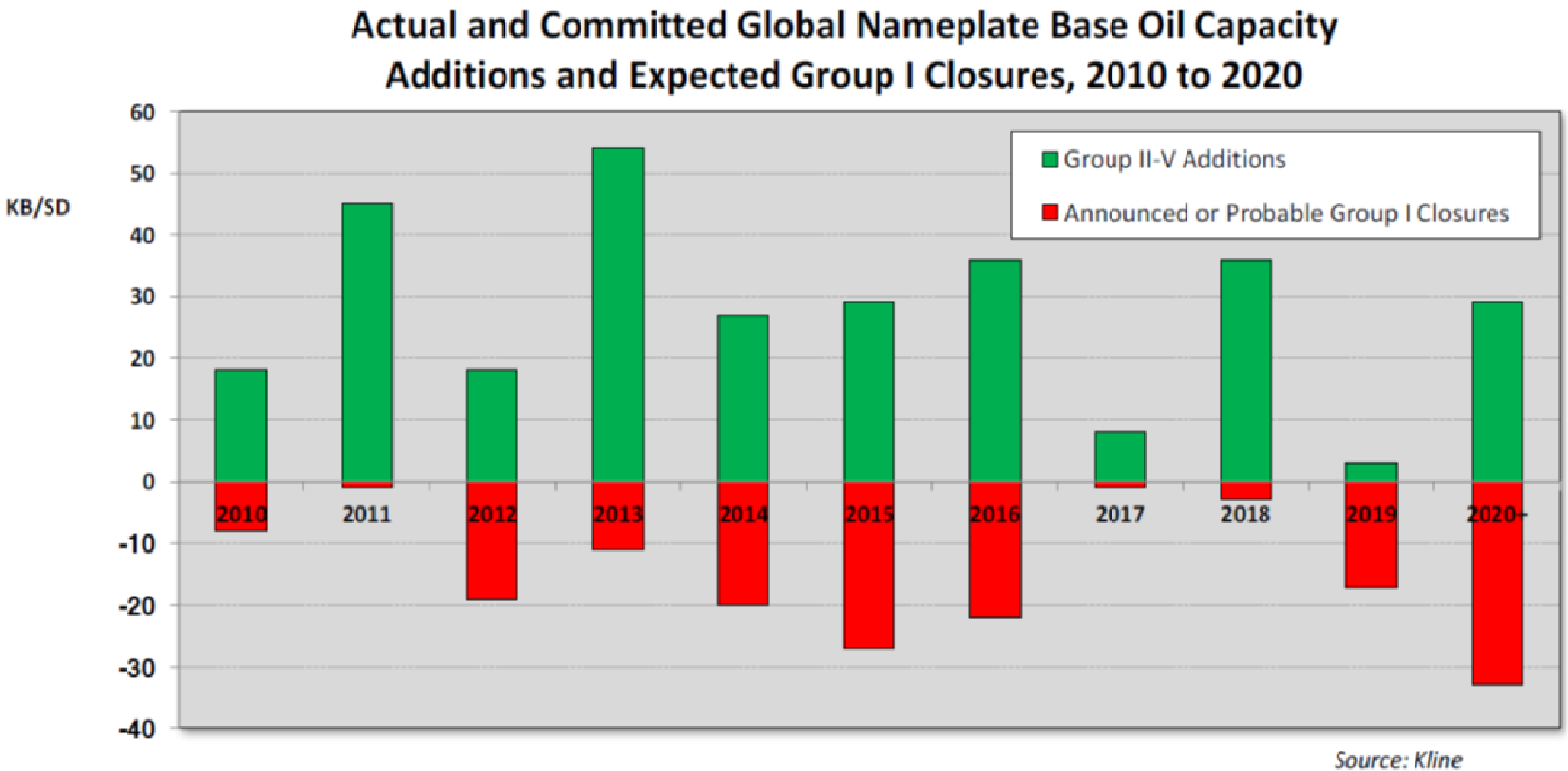
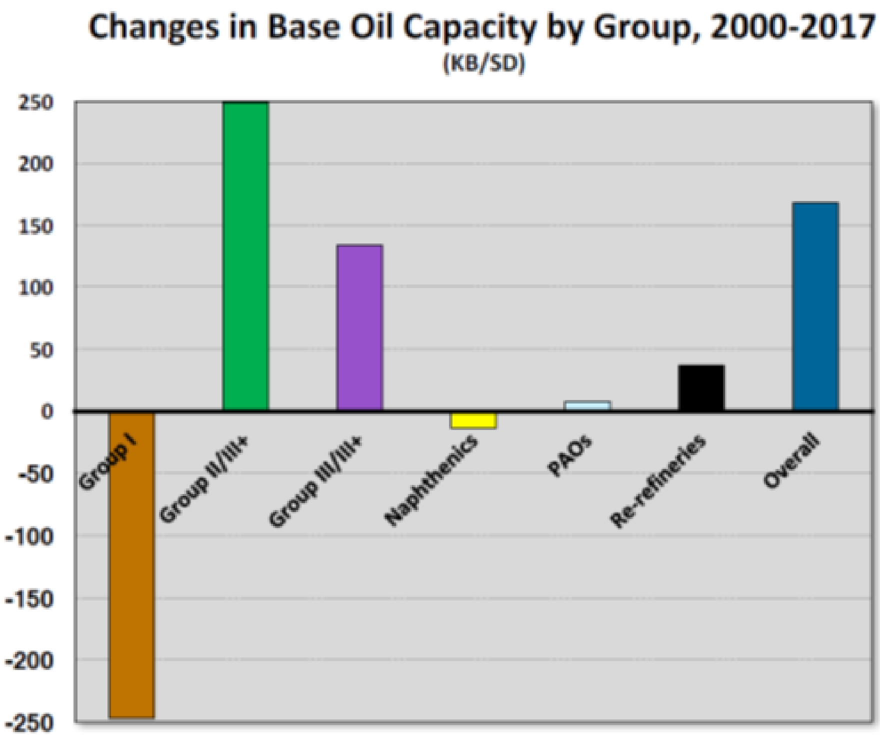
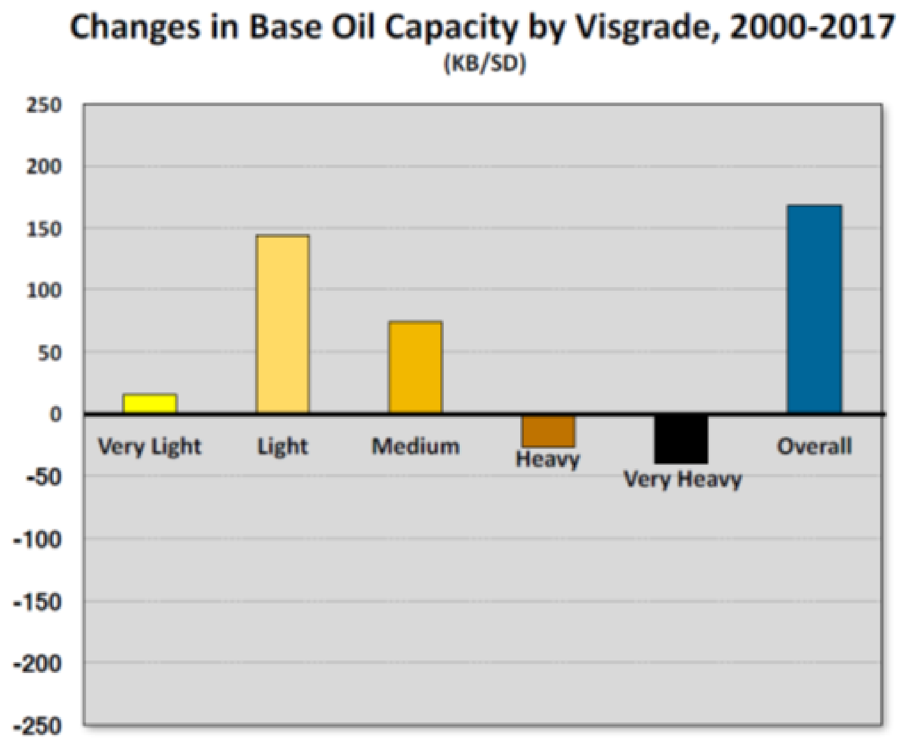


Nearly 150 KB/D of Group I capacity could be decommissioned during this decade, and another 100-150 KB/D is "At Risk" from low margins/refinery shutdowns by 2030

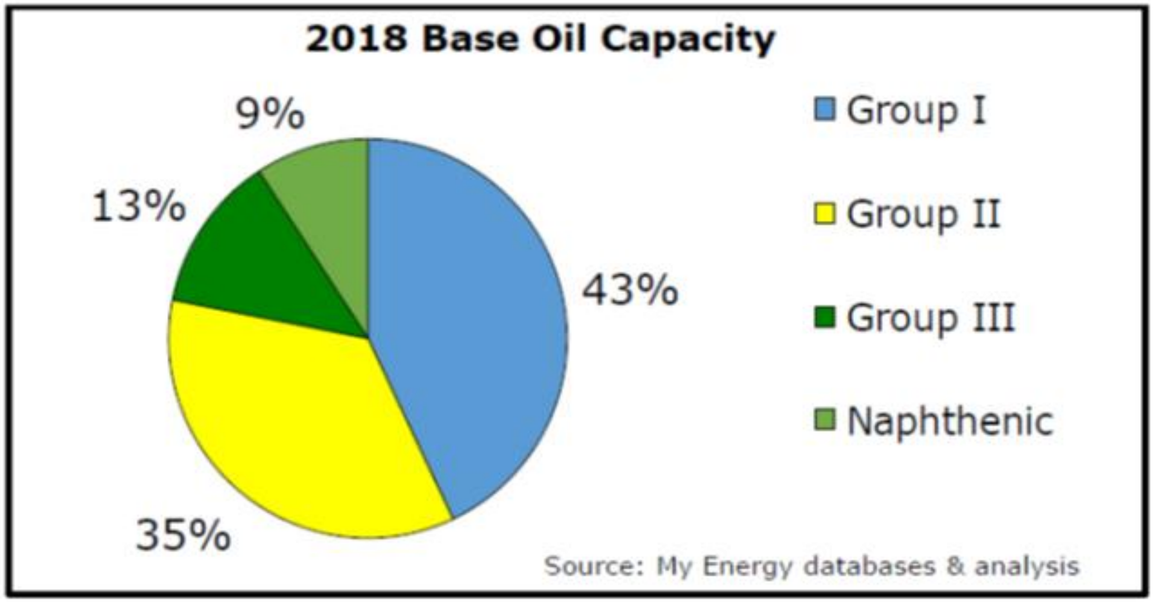
Base Oil – Changes in global production





Source: Kline

Base Oil Global Demands



Group I	23500 mT
Group II	19500 mT
Group III	7000 mT
Naphthenic	5000 mT

Total ~ 55 MMT
~ 80% avg. global capacity utilization
(supply ~ 44 MMT)

Thank you !

Thank You for Your Attention !