This presentation includes forward-looking statements. Actual future conditions (including economic conditions, energy demand, and energy supply) could differ materially due to changes in technology, the development of new supply sources, political events, demographic changes, and other factors discussed herein (and in Item 1A of ExxonMobil’s latest report on Form 10-K or information set forth under “factors affecting future results” on the “investors” page of our website at www.exxonmobil.com). This material is not to be reproduced without the permission of ExxonMobil Corporation.

CIS BASE OILS AND LUBRICANTS
21-23 May, Moscow, Russia

Quality lube base oil from hydrodewaxing

Energy lives here™

Evguenia Copley
Agenda

• Base stock and lubricant trends
• Catalytic lube dewaxing and hydrofinishing
• Refinery considerations
Base stock and lubricant trends
It all started with the wheel

3000 BC

Olive oil
Animal fat
Vegetable oil

1850s

More crude oil

1860s

Start of "modern" refining

1911

SEA oil classification

1919

API standardization

1936

1st cat. oil cracking

1942

1st fluid cat cracking

1820s

Clay / acid treating

1920s

1930s

Solvent process

1950s

Hydro-treating

1981

MLDW™

1993

1999

1997 2000 2005 .... MSDW™

2003

2005

MWI™
Global lubricant demand & segmentation

- Demand growth in developing markets
  - Developing market ~ 2%
  - Developed market stable

- Automotive lubricants ~half of market
  - Passenger vehicle lubes (cars)
  - Commercial vehicle lubes (trucks)

- Industrial, Marine, Process Oil remainder

Source: EM assessment of publicly available information.
Lubricant relative composition & cost estimates

- Base oils account for ~80-95% of composition, ~50-75% of lubricant cost
- Have significant impact on lubricant performance and economics

* ExxonMobil assessment of typical cost distribution for example products blended in a medium sized European blend plant with waterborne access
### API base oils classification

<table>
<thead>
<tr>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
<th>Group IV</th>
<th>Group V</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 &lt; VI &lt; 120</td>
<td>80 &lt; VI &lt; 120</td>
<td>VI &gt; 120</td>
<td>PAOs</td>
<td>SYNTHETIC ESTERS</td>
</tr>
<tr>
<td>% sat &lt; 90%</td>
<td>% sat &gt; 90%</td>
<td>% sat &gt; 90%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% S &gt; 0.03</td>
<td>% S &lt; 0.03</td>
<td>% S &lt; 0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 and 2-R Aromatics</td>
<td>Naphthenes</td>
<td>Iso-paraffins</td>
<td>single component</td>
<td></td>
</tr>
<tr>
<td>Naphthenes</td>
<td>Iso-paraffins</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polar Compounds</td>
<td>n-paraffins</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iso-paraffins</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n-paraffins</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This classification is very widely used. Modern production is Group-II and Group-III.
Lubricant trends impact on base stocks

Application trends, basestock impact

- Fuel economy
- Severe sub-categories
- Composition constraints
- Heavy duty EO
- Passenger car EO
- Diluent oil
- Marine
- Industrial
- Oil life
- Increasing quality
- Changing TBN and fuels

Source: EM assessment of publically available information.
Evolving base stock supply and demand

Group II & III demand growth
- Improved performance
- Increasing availability
- Cost competitiveness

Group I demand declining (especially light viscosity)
- Performance constraints
  - Sulfur limits
  - Soot handling
  - Oxidation stability
  - Volatility limits
- Supply uncertainty

Source: EM assessment of publically available information.
## Base stock composition impact

<table>
<thead>
<tr>
<th>Molecule</th>
<th>Structure</th>
<th>VI</th>
<th>Low Temp</th>
<th>Oxidation</th>
<th>Solubility</th>
<th>Toxicity</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>n-paraffin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Dewaxing</td>
</tr>
<tr>
<td>Iso-paraffin</td>
<td></td>
<td>Good/</td>
<td>Good</td>
<td>Excellent</td>
<td>Good</td>
<td>Low</td>
<td>Base stock</td>
</tr>
<tr>
<td>Linear naphthenic</td>
<td></td>
<td></td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Naphthenic</td>
<td></td>
<td>Poor</td>
<td>Excellent</td>
<td>Good</td>
<td>Excellent</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Substituted Monoaromatics</td>
<td></td>
<td>Poor</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Medium</td>
<td>Hydro-processing</td>
</tr>
<tr>
<td>Poly Nuclear Aromatics</td>
<td></td>
<td>Poor</td>
<td>Poor</td>
<td>Very Poor</td>
<td>Good</td>
<td>Very high</td>
<td></td>
</tr>
</tbody>
</table>

- Sulfur and nitrogen in crudes are reduced or practically eliminated in refinery processing
- Sulfur can contribute to oxidation stability in conventionally refined base oil
- Nitrogen can contribute to product color and is generally eliminated in processing
Catalytic lube dewaxing and hydrofinishing
Base oil processing schemes

Manufacturing processes

- Physical separation
  - Group I

- Moderate severity HC
  - Catalytic dewaxing
  - Hydrofinishing
  - Group II

- High severity HC
  - Catalytic dewaxing
  - Hydrofinishing
  - Group III

- Catalytic rearrangement
  - Catalytic dewaxing
  - Hydrofinishing
  - Group III+

Source: ExxonMobil Research & Engineering
ExxonMobil’s all catalytic processing path

**Vacuum Gas Oil**

- **Hydroprocessing** (UOP Unicracking™)
  - **VGO**
    - 40 - 60% Aromatics
    - 2-3 Wt-% Sulfur
    - 70-85 Waxy VI
    - +25-50°C Pour Point
    - L3.0-L4.0 Color\(^{(1)}\)

  - **After Hydrocracking**
    - <10% Aromatics
    - <10 ppm Sulfur
    - >130 Waxy VI
    - +30-40°C Pour Point
    - L0.5-L2.0 Color\(^{(1)}\)

- **Catalytic dewaxing** (MSDW™)
  - **After MSDW™**
    - <2% Aromatics
    - <5 ppm Sulfur
    - >120 Dewaxed VI
    - <15°C Pour Point
    - ~+20 Color\(^{(2)}\)

- **Hydrofinishing** (MAXSAT™)
  - **After MAXSAT™**
    - <1% Aromatics
    - <1 ppm Sulfur
    - >120 Dewaxed VI
    - <15°C Pour Point
    - +30 Color\(^{(2)}\)

**Improvements**

- Improve VI
- Reduce sulfur & nitrogen
- Saturate aromatics
- Reduce CCR
- Remove metals

- Improve cold flow properties
- Convert wax to high VI lube

- Improve color & stability
- Saturate polynuclear aromatics

\(^{(1)}\) ASTM, \(^{(2)}\) Saybolt
First commercial example

High catalytic activity for longer operating life
MSDW™ high catalytic dewaxing activity [Refinery-1]

- Low aging rate over more than 11-year operation on same catalyst load
  - High selectivity maintained over catalyst cycle - No yield degradation
  - > 95% service factor over catalyst life (11+ years) - Exceptional reliability
- Licensee increased UCO feed rate by about 20% over catalyst cycle

UCO at 1.7 h⁻¹ LHSV
Group-2 Production

MSDW ART (°C)

Days on Oil

0 500 1,000 1,500 2,000 2,500 3,000 3,500 4,000

- 4.0 cSt Aging Rate: 1.5 °C/year
- 6.5 cSt Aging Rate: 1.4 °C/year
- 11.5 cSt Aging Rate: 1.8 °C/year
MSDW™ catalyst higher activity provides

Longer cycle length
- 3x and 4x Hydrocracker cycle life
- Catalyst saving
- Precious metals (Platinum, Palladium) saving

Operation at higher LHSV
- Lower catalyst volume compared to competition
- Lower precious metals (Platinum, Palladium) requirement per fill
- Lower capital investment (smaller reactors)

Simple and steady operation

Feed flexibility, allows higher levels of contaminants
- Potential H/C cycle length extension
- Challenged crudes

Estimated benefits:
2 - 5 M$ per year
Second commercial example

High yield maintenance for high profitability
Demonstrate high yield maintenance  [Refinery-2]

- Increased profitability and return on investment
- Group-II base oil, with very high saturates maintained
What is the advantage of high yield maintenance?

- Base case:
  - 20 KBD unit
  - 8-year cycle
- MSDW™ unit exhibits 1-2% yield advantage at SOR
- Maintains yield through catalyst life better than alternative technologies

Estimated benefits over 8 years:

> 800,000 bbls additional base oil
Third commercial example

Excellent robustness for high reliability
Robustness an added advantage [Refinery-3]

Customer issue
• LBO plant has no control over refinery operation
• Refinery hydrocracker HP Heat Exchanger leak
• UCO contaminated with raw VGO (containing coker GO)
  • High Nitrogen
  • High Sulfur, Aromatics and PNA contaminants

ExxonMobil solution
• High activity and robust MSDW and MAXSAT catalysts
• Avoid shut-down or turn-down capacity
  • Operated with >10wppm Nitrogen for 2-years
• Achieved catalysts guaranteed life

Value
• Maintain high quality base oil (Gp.III) production at full capacity
• No yield debit
• No early catalyst replacement

Estimated value to customer during the upset:
75 M$
Exceptional 13-year run length [Refinery-3]

- No yield debit observed over 13 years on the initial catalyst fill
  - No quality issues
  - Aging rate < 2°C per year
Commercial experience

Maximizing return on capital
Maximizing profitability with high productivity

Increase base oil production by taking advantage of:

- Lower SOR temperature
- Low catalyst aging rate
- Increased feed rate
- High LHSV (up to 2.8 h⁻¹)

Unparalleled productivity

<table>
<thead>
<tr>
<th>Unit operation</th>
<th>Nitrogen range (wppm)</th>
<th>Productivity (m³ feed processed / m³ catalyst)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean</td>
<td>&lt; 3</td>
<td>&gt; 150,000 - Three units at about 100,000</td>
</tr>
<tr>
<td>Semi-clean</td>
<td>3 &lt; N &lt; 7</td>
<td>Up to 65,000 - Catalyst changed before EOR (HC turn around)</td>
</tr>
<tr>
<td>“Dirty”</td>
<td>N &gt; 7</td>
<td>Up to 35,000 - Catalyst changed before EOR (HC turn around)</td>
</tr>
</tbody>
</table>
Value of superior dewaxing technology

**High activity and activity maintenance**
- Lower investment (smaller Rx, less catalyst, increased life cycle)
- High throughput

**High selectivity**
- Increase yield / profit

**Feed range and feed flexibility**
- Single catalyst system maximizing production of LN to HN

**Tolerance to feed contaminants**
- Feed flexibility (including UCO import)
- Tolerance to upsets

---

**Value of additional 1% yield:**
- 400,000 tpa unit
- At recent gulf coast prices(*)
- 2 – 3 M$/y vs. ULSD
- 4 – 5 M$/y revenues

(*)
- Group-II 780 $/t
- Group-III 1,300 $/t
- ULSD 580 $/t

Source: U.S. Base Oil Price Report from Lube Report magazine
Commercial experience is critical

MSDW™ and MAXSAT™ technologies are proven!

- Over 30 licenses, also an operator
- Two reactors system (cascade)
  - Reactor-1: Dewaxing
  - Reactor-2: Hydrofinishing
- Process full range of feed from light neutral to Bright stock

Best technology solution

- Highest activity
  Lower capital cost, smaller reactors
- High selectively for highest base oil yields
  Increase profit
- Demonstrated yield maintenance
  Increase return on investment
- High contaminants tolerance
  Highest reliability
- Value-added through customer support
Refinery considerations
Technology selection

Understand your needs
- Regional and export market
- Individual company needs
- Long-term selection
- Flexibility

How to select the best technology -- ECONOMICS
- Investment costs
  - Equipment size
  - Catalyst and precious metals
- Activity (SOR)
- Yields (SOR)
- Yields and activity maintenance
  - Aging
  - Base oil production per catalyst unit volume
- Reliability: robustness and resistance to upsets
- Commercial experience
Thank you

Disclaimer

©2019 ExxonMobil. ExxonMobil, the ExxonMobil logo, the interlocking “X” device and other product or service names used herein are trademarks of ExxonMobil, unless indicated otherwise. This document may not be distributed, displayed, copied or altered without ExxonMobil’s prior written authorization. To the extent ExxonMobil authorizes distributing, displaying and/or copying of this document, the user may do so only if the document is unaltered and complete, including all of its headers, footers, disclaimers and other information. You may not copy this document to or reproduce it in whole or in part on a website. ExxonMobil does not guarantee the typical (or other) values. Any data included herein is based upon analysis of representative samples and not the actual product shipped. The information in this document relates only to the named product or materials when not in combination with any other product or materials. We based the information on data believed to be reliable on the date compiled, but we do not represent, warrant, or otherwise guarantee, expressly or impliedly, the merchantability, fitness for a particular purpose, freedom from patent infringement, suitability, accuracy, reliability, or completeness of this information or the products, materials or processes described. The user is solely responsible for all determinations regarding any use of material or product and any process in its territories of interest. We expressly disclaim liability for any loss, damage or injury directly or indirectly suffered or incurred as a result of or related to anyone using or relying on any of the information in this document. This document is not an endorsement of any non-ExxonMobil product or process, and we expressly disclaim any contrary implication. The terms “we,” “our,” "ExxonMobil Chemical" and “ExxonMobil” are each used for convenience, and may include any one or more of ExxonMobil Chemical Company, Exxon Mobil Corporation, or any affiliate either directly or indirectly stewarded.