Shale Crudes (Tight Oil or “LTO”): Base Oil Impacts

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My Energy
Shale Crudes (Tight Oil or “LTO”): Base Oil Impacts

- US Shale Resources
  - Terminology & naming conventions
  - Major fields

- Impact on Base Oil Supply
  - Comparison of LTO versus other crudes
  - Refinery implications for base oils

- Outlook / conclusions – looking ahead
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Historical Terminology for Shale Resources

- Historical “shale oil” production required thermal processing.

**Thermal Cracking / Retorting 1000 °F**

“Oil Shale” or Kerogen, a crude oil precursor

“Shale Oil” – synthetic crude sometimes called “Shale crude”

- Expensive operation to produce crude, similar in cost to oil sands in western Canada.
Today’s New Shale Resource Recovery

- Today’s “shale oil” is naturally occurring crude oil trapped in shale formations – no thermal processing required

Hydraulic Fracturing / Horizontal Drilling

Crude oil and gas previously inaccessible

- Became economically viable with new recovery techniques

“Shale Oil” or “Shale Crude” (and shale gas)
“Shale Crude” terminology led to confusion

- Old or new – both are shale derived crude oils

- Industry confusion – needed a different naming convention
Today’s “shale oil” needed a new name

- Global agencies changed shale oil terminology 2013 - 2014

- Shale is a low-permeability or “tight” geological formation
  - In contrast to typical sandstone, other porous formations
  - Lighter crude oils and gases are trapped in low porosity formations

- International Energy Agency (IEA) uses “light tight oil” or LTO to describe naturally occurring crude recovered from shale, clay, chalk, or other non-porous formations
- US Energy Information Administration (EIA) uses both “tight oil” and LTO
Conventional Oil vs. Tight Oil Recovery

- Tight oils require unconventional drilling techniques at much deeper locations – historically uneconomic
US Tight Oil Major Fields

- Seven regions; over 90% of US oil production growth since 2010
  - Bakken and Eagle Ford are primary new oil producing areas
Why LTO matters to base oils

- Tight oil is currently ~ 50% of today’s US crude oil production & being run in US refineries which produce base oils
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Select US crude yields & gravity
Typically run in refineries making base oils

- Refineries configured differently to handle light vs heavy crudes
- However, VGO yield typically 25% - 30% regardless of API gravity

Source: My Energy assay database compiled from public domain crude assays; patents; and papers given at Upstream conferences.
LTO yields vs. other crudes for base oils

- LTOs have more naphtha, less VGO, and less resid
- Bakken VGO yield similar to WTI, Eagle Ford much lighter
- API gravity of LTO VGO is lighter than traditional VGO
LTO variability: °API ranges from 37 to 76

- Gravity > 45°API is not crude; classified as condensate
- Condensate sells for less than crude; producers blend to 45°API with material in excess of 60 °API
- Assays vary; some with VGO yield as low as 15%

*Less total VGO as feed, less heavy neutral precursors, more cracking = lighter base oil*
What happens when a refinery runs LTO?

- More fuel products removed in atmospheric distillation, less feed to vacuum distillation where base oils are made.
What about refineries producing Group I base oils?

- Most refineries have excess VGO – some to Group I base oil units, remainder to fuels cracking
- ... but LTO resid yields are low – curtails Bright Stock production unless run in admixture with other crudes
What about refineries producing Group I base oils?

- LTOs have enough VGO yield to supply a typical Group I base oil plant.
- Less impact vs. Group II refineries where the VGO is fed to hydrocracking.
- However, LTO runs to Group I refineries could reduce Bright Stock production (low resid yields).
LTOs have bigger impact on Group II plants

- Percentage of VGO has decreased, but likely adequate to feed base oil HCU
- Lighter gravity VGO feed to HCUs produces lighter byproducts
- Lower contaminants, more easily cracked, leading to over-cracking vs historical feeds

Result: Increased naphtha, diesel, and light base oils production at the expense of mid viscosity and heavy viscosity base oils
LTOs produce more fuel products at the expense of Group II base oils

- Result: Increased naphtha, diesel, and light base oils production at the expense of mid viscosity and heavy viscosity base oils
VGO of traditional crudes versus LTO crudes

• Good news: less contaminants, more paraffinic
• Bad news:
  - less of it (~ 20% versus historically 25% - 30%)
  - higher API gravity means lighter feed to base oil HCU
  - more easily over-cracked to lighter products

Source: AFPM 2014 Annual Meting AM-14-15 Challenges of Processing Feeds Derived from Tight Oil Crudes in the Hydrocracker (Criterion Catalysts & Technologies)
Lighter refinery crude runs – with lighter VGO

1985 to 2015 Texas Gulf Coast Refinery
°API Gravity of Crude Oil Input to Refineries

- Lighter crudes historically run with no base oil impact ... but ...
- Historical crudes 25% - 30% VGO regardless of API gravity
- LTOs have less VGO, and VGO is lighter than historical
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Going forward: how much LTO will be run in refineries making base oil?

Two major offsetting factors

- LTO crude price advantage relative to light imports and WTI; brings higher LTO runs especially into USGC refineries

- LTO crude output may be curtailed with sustained low crude prices
US refineries have incentive to back out light imports & light domestic crude in favor of LTOs

**Example crude runs: July 2015**

<table>
<thead>
<tr>
<th>Refinery</th>
<th>Crude Runs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chevron Richmond</td>
<td>Domestic + KSA</td>
</tr>
<tr>
<td>Chevron Pascagoula</td>
<td>Domestic + Venezuela</td>
</tr>
<tr>
<td>HollyFrontier</td>
<td>Domestic + Canada</td>
</tr>
<tr>
<td>Motiva Pt Arthur</td>
<td>Domestic + KSA, Light Mexican, KSA</td>
</tr>
<tr>
<td>Phillips 66 Lake Charles</td>
<td>Domestic + KSA, Mexico, Brazil, Columbia</td>
</tr>
</tbody>
</table>

Source: My Energy database compiled from EIA company level import data, company websites, and public presentations
LTO production highly dependent on crude prices

- USA monthly tight oil output has fallen since March 2015
EIA base case forecast shows 2018 LTO peak

- Good news for base oils if reference case holds, or if “low resource” case occurs (even lower crude prices)
- Not good news if crude prices rise above $80 - $90 / b
Eagle Ford Production is falling on low crude prices

<table>
<thead>
<tr>
<th>Month</th>
<th>Production</th>
<th>Mth Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar-15</td>
<td>1,726,302</td>
<td>-1,701</td>
</tr>
<tr>
<td>Apr-15</td>
<td>1,724,602</td>
<td>-24,625</td>
</tr>
<tr>
<td>May-15</td>
<td>1,699,977</td>
<td>-38,263</td>
</tr>
<tr>
<td>Jun-15</td>
<td>1,661,714</td>
<td>-49,318</td>
</tr>
<tr>
<td>Jul-15</td>
<td>1,612,395</td>
<td>-56,477</td>
</tr>
<tr>
<td>Aug-15</td>
<td>1,555,918</td>
<td>-57,993</td>
</tr>
<tr>
<td>Sep-15</td>
<td>1,497,925</td>
<td>-61,136</td>
</tr>
<tr>
<td>Oct-15</td>
<td>1,436,789</td>
<td>-70,951</td>
</tr>
<tr>
<td>Nov-15</td>
<td>1,365,838</td>
<td>-87,838</td>
</tr>
<tr>
<td>Dec-15</td>
<td>1,278,000</td>
<td></td>
</tr>
</tbody>
</table>

- Still significant amounts, but going lower, not higher
<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>Tight Oil reserves billion barrels,</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Russia</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>United States</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>China</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Argentina</td>
<td>27</td>
<td>Vaca Muerta 2020; fuels refineries closer than La Plata</td>
</tr>
<tr>
<td>5</td>
<td>Libya</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Australia</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Venezuela</td>
<td>13</td>
<td>La Luna / Maracaibo; 2030+</td>
</tr>
<tr>
<td>8</td>
<td>Mexico</td>
<td>13</td>
<td>2030+; ownership and taxation issues</td>
</tr>
<tr>
<td>9</td>
<td>Pakistan</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Canada</td>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>

- **Verdict:** Argentina possible, others unlikely near term
Conclusions for base oils

- Since 2014, tight oils are contributing to lower Group II heavy neutral output, and more 3cSt and 4 cSt material
  - Less % VGO in crude, lighter API gravity, cracks more easily

- Tight oils run in Group I refineries have less impact
  - VGO is lighter, but ample - and not cracked
  - Bright stock yields could be negatively impacted by LTO runs, but no 2014 – 2015 reduction observed
Conclusions for base oils

- Market supply – demand fundamentals leading to upward pricing pressure on heavy neutrals and bright stock relative to light neutrals

- Same regardless of Group I vs Group II vs naphthenic

- Margin improvement for Group I plants vs Group II plants running LTOs

- Naphthenics also see margin improvement from pricing on heavy pale oils and naphthenic bright stock

Photo courtesy of Dr. H. E. Henderson, KEPC Consulting
LTO outlook for US refineries?

Tell me the price of crude in 2020 and I’ll give you a tight oil outlook.
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Supply/Demand, Trade Analysis
Price Mechanisms, Mfg Economics
Base Oils, Waxes, GTL
Training: Group and Private
Due Diligence; Litigation Support
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