Overview
Gas & NGL Processing
Topics

Energy consumption & natural gas’s place
- Natural gas sources
- Relationship with petroleum

Basic economics of natural gas & NGL
- Trends for prices
- What are appropriate margins for the industry?

Gas processing as part of total production system
Energy consumption & natural gas’s place
Growth of U.S. Energy Consumption


Updated: January 16, 2018
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World Energy Consumption by Source

Growth will not be uniform among all energy sources

- Renewable & nuclear power projected to be fastest-growing energy sources, increasing by 2.5% per year
- Natural gas fastest growing fossil fuel, increasing by 1.7% per year
- Coal grows faster than petroleum because of China’s increasing consumption

http://www.eia.gov/forecasts/ieo/
Energy Markets Are Interconnected

Estimated U.S. Energy Consumption in 2016: 97.3 Quads

Sources: LLNL March, 2017. Data is based on DOE/EIA MDR (2016). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy under whose auspices the work was performed. This chart was revised in 2017 to reflect changes made in mid-2016 to the Energy Information Administration’s analysis methodology and reporting. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. Net-use efficiency is estimated as EIA for the residential sector, 41% for the commercial sector, 23% for the transportation sector, and 49% for the industrial sector which was updated in 2017 to reflect EIA’s analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-NN-414527

https://flowcharts.llnl.gov/commodities/energy
Origins of Oil & Gas

- Organic life buried in sedimentary rock
- Transformation to hydrocarbons
- Migration from source rocks
- Accumulation of oil & gas
- Flow of oil & gas through porous media

Oil forms throughout a temperature range from about 150 to 300 degrees F (the oil window.) Thermogenic natural gas is formed at temperatures above 300 degrees F.
Petroleum & Natural Gas

Consumption influenced by production & cost of fuels

Figure 33. World oil prices in three cases, 1990-2040 (2011 dollars per barrel, Brent crude oil)

Figure 34. World liquids consumption in three oil price cases, 2010 and 2040 (million barrels per day)

Figure 40. World natural gas consumption, 2010-2040 (trillion cubic feet)
Flow of Natural Gas in U.S.

Natural Gas Annual, 2014
https://www.eia.gov/naturalgas/annual/

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Overview of Natural Gas Gathering & Processing

Fundamentals of Natural Gas Processing, 2nd ed.  
Kidnay, Parrish, & McCartney
Natural Gas Resources

Petroleum & natural gas formed from decomposing organic matter in “source rock”

Conventional – gas & liquids migrate through permeable rock toward the surface until it is stopped by some trapping mechanism

Unconventional – gas & liquids are trapped at the source rock because of extremely low permeabilities

North American Conventional Gas Fields


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North American Offshore Gas Fields

Source: Energy Information Administration based on data from MMS, HPDI, CA Dept of Oil, Gas & Geothermal
Updated: April 8, 2008

North American Shale Gas Plays

North American shale plays
(as of May 2011)

Source: U.S. Energy Information Administration based on data from various published studies. Canada and Mexico plays from API. Updated: May 9, 2011

Marcellus & Utica Shale Formation Map

http://marcelluscoalition.org/pa-map/
Worldwide Shale Oil & Gas

Shale oil & gas have the potential to dramatically alter world energy markets.

Source: Supplemental presentation is support of International Energy Outlook 2013, U.S. Energy Information Agency
http://www.eia.gov/forecasts/ieo/
Expected Natural Gas Production by Source

Figure MT-46. U.S. dry natural gas production by source in the Reference case, 1990–2040

Retrieved November 26, 2016
http://www.eia.gov/energy_in_brief/article/shale_in_the_united_states.cfm
U.S. Gas Processing & Transportation

http://www.eia.gov/state/maps.cfm?v=Natural%20Gas

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Gas Plants Capacities in U.S. Lower 48

Natural gas processing plant capacity in the United States, 2014

http://www.eia.gov/todayinenergy/detail.cfm?id=8530
U.S. Gas Transportation, Storage, & Terminals

http://www.eia.gov/state/maps.cfm?v=Natural%20Gas

Updated: January 16, 2018
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Interstate Natural Gas Flow

Figure 13. Principal Interstate Natural Gas Flow Capacity Summary, 2014

Natural Gas Annual, 2014
https://www.eia.gov/naturalgas/annual/

Updated: January 16, 2018
Copyright © 2017 John Jechura (jjechura@mines.edu)
Basic economics of natural gas & NGL
Energy & Oil Prices

Prices retrieved January 1, 2018
http://www.bloomberg.com/energy/
Energy & Oil Prices

**MONT BELVIEU LDH PROPANE (NYMEX:B0)**

<table>
<thead>
<tr>
<th>Market</th>
<th>Contract</th>
<th>Open</th>
<th>High</th>
<th>Low</th>
<th>Last</th>
<th>Change</th>
<th>Pct</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>B0.Z17.E</td>
<td>Dec 2017 (E)</td>
<td>0.90000</td>
<td>0.90000</td>
<td>0.90000</td>
<td>0.95920</td>
<td>+0.0693</td>
<td>+0.08%</td>
<td>set 16 11</td>
</tr>
<tr>
<td>B0.F18.E</td>
<td>Jan 2018 (E)</td>
<td>0.92500</td>
<td>0.92500</td>
<td>0.92500</td>
<td>0.98000</td>
<td>+0.06437</td>
<td>+0.45%</td>
<td>set 16 11</td>
</tr>
<tr>
<td>B0.G18.E</td>
<td>Feb 2018 (E)</td>
<td>0.97375</td>
<td>0.97375</td>
<td>0.97375</td>
<td>0.97375</td>
<td>+0.06437</td>
<td>+0.45%</td>
<td>set 16 11</td>
</tr>
</tbody>
</table>

**NAPHTHA CARGOES CIF NWE (PLATTS) (NYMEX:UN)**

<table>
<thead>
<tr>
<th>Market</th>
<th>Contract</th>
<th>Open</th>
<th>High</th>
<th>Low</th>
<th>Last</th>
<th>Change</th>
<th>Pct</th>
<th>Time</th>
</tr>
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<tbody>
<tr>
<td>U.N.Z17.E</td>
<td>Dec 2017 (E)</td>
<td>576.553</td>
<td>576.553</td>
<td>576.553</td>
<td>576.553</td>
<td>+0.109</td>
<td>+0.02%</td>
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<tr>
<td>U.N.G18.E</td>
<td>Feb 2018 (E)</td>
<td>588.062</td>
<td>588.062</td>
<td>588.062</td>
<td>588.062</td>
<td>+8.423</td>
<td>+1.49%</td>
<td>set 17 11</td>
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</table>

**NATURAL GAS (NYMEX:NG)**

<table>
<thead>
<tr>
<th>Market</th>
<th>Contract</th>
<th>Open</th>
<th>High</th>
<th>Low</th>
<th>Last</th>
<th>Change</th>
<th>Pct</th>
<th>Time</th>
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</thead>
<tbody>
<tr>
<td>NG.F18.E</td>
<td>Jan 2018 (E)</td>
<td>2.639</td>
<td>2.762</td>
<td>2.558</td>
<td>2.738</td>
<td>+0.095</td>
<td>+3.68%</td>
<td>set 14 30</td>
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<tr>
<td>NG.G18.E</td>
<td>Feb 2018 (E)</td>
<td>2.930</td>
<td>3.008</td>
<td>2.620</td>
<td>2.963</td>
<td>+0.038</td>
<td>+1.29%</td>
<td>set 14 30</td>
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<tr>
<td>NG.H18.E</td>
<td>Mar 2018 (E)</td>
<td>2.866</td>
<td>2.955</td>
<td>2.673</td>
<td>2.900</td>
<td>+0.022</td>
<td>+0.70%</td>
<td>set 14 30</td>
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</tbody>
</table>

**NATURAL GAS (E-MINI) (NYMEX:QG)**

<table>
<thead>
<tr>
<th>Market</th>
<th>Contract</th>
<th>Open</th>
<th>High</th>
<th>Low</th>
<th>Last</th>
<th>Change</th>
<th>Pct</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>QG.G18.E</td>
<td>Feb 2018 (E)</td>
<td>2.930</td>
<td>3.010</td>
<td>2.620</td>
<td>2.955</td>
<td>+0.035</td>
<td>+1.18%</td>
<td>set 14 30</td>
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<tr>
<td>QG.H18.E</td>
<td>Mar 2018 (E)</td>
<td>2.885</td>
<td>2.955</td>
<td>2.600</td>
<td>2.905</td>
<td>+0.020</td>
<td>+0.70%</td>
<td>set 14 30</td>
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<tr>
<td>QG.J18.E</td>
<td>Apr 2018 (E)</td>
<td>2.725</td>
<td>2.770</td>
<td>2.725</td>
<td>2.750</td>
<td>+0.030</td>
<td>+1.09%</td>
<td>set 14 30</td>
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</table>

**NATURAL GAS (TAS) (NYMEX:NGT)**

<table>
<thead>
<tr>
<th>Market</th>
<th>Contract</th>
<th>Open</th>
<th>High</th>
<th>Low</th>
<th>Last</th>
<th>Change</th>
<th>Pct</th>
<th>Time</th>
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</thead>
<tbody>
<tr>
<td>NGT.G18.E</td>
<td>Feb 2018 (E)</td>
<td>-1</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>+2</td>
<td>0.00%</td>
<td>set 14 30</td>
</tr>
<tr>
<td>NGT.H18.E</td>
<td>Mar 2018 (E)</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>-50.00%</td>
<td>set 14 30</td>
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<tr>
<td>NGT.J18.E</td>
<td>Apr 2018 (E)</td>
<td>-1</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>-2</td>
<td>-100.00%</td>
<td>set 14 30</td>
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</tbody>
</table>

Prices retrieved January 1, 2018


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Price Changes With Time

Natural Gas Daily Spot Price (Henry Hub)

Prices updated January 1, 2018
Sources: [http://tonto.eia.doe.gov/dnav/pet/pet_pri_spt_s1_d.htm](http://tonto.eia.doe.gov/dnav/pet/pet_pri_spt_s1_d.htm) & [http://www.eia.gov/dnav/ng/ng_pri_fut_s1_d.htm](http://www.eia.gov/dnav/ng/ng_pri_fut_s1_d.htm)
Price Changes With Time

Natural Gas & WTI Daily Spot Prices

Prices updated January 1, 2018
Sources: http://tonto.eia.doe.gov/dnav/pet/pet_pri_spt_s1_d.htm & http://www.eia.gov/dnav/ng/ng_pri_fut_s1_d.htm
No Such Thing as a “Global” Gas Price

There has always been a major disparity between regional prices

In 2012, Henry Hub in the United States averaged $2.76/MMBtu; the price in Japan was $16.75/MMBtu

European pricing was somewhere in the middle: $9.46/MMBtu in the UK to $11.03/MMBtu in Germany

SOURCE: BP STATISTICAL REVIEW OF WORLD ENERGY (JUNE 2013)

http://www.slideshare.net/enalytica/gas-market-outlook-lng-business-fundamentals
NGLs Can Bring Value

Propane Daily Spot Price (Henry Hub)

Prices updated January 1, 2018
Sources: http://tonto.eia.doe.gov/dnav/pet/pet_pri_spt_s1_d.htm & http://www.eia.gov/dnav/ng/ng_pri_fut_s1_d.htm
NGLs Can Bring Value

Propane & WTI Spot Prices

Prices updated January 1, 2018
Sources: http://tonto.eia.doe.gov/dnav/pet/pet_pri_spt_s1_d.htm & http://www.eia.gov/dnav/ng/ng_pri_fut_s1_d.htm

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NGLs Can Bring Value

Propane & Natural Gas Spot Prices

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Sources: [http://tonto.eia.doe.gov/dnav/pet/pet_pri_spt_s1_d.htm](http://tonto.eia.doe.gov/dnav/pet/pet_pri_spt_s1_d.htm) & [http://www.eia.gov/dnav/ng/ng_pri_fut_s1_d.htm](http://www.eia.gov/dnav/ng/ng_pri_fut_s1_d.htm)
Economic “Spreads”

NGL Frac spread

- Difference between the value of components in NGL vs. retaining in the natural gas
  
  \[
  \text{Frac Spread} = (\text{Value as liquid product}) - (\text{Value as component of natural gas})
  \]

- Can include value of mixture of \( \text{C}_2, \text{C}_3, \text{iC}_4, \text{nC}_4, \text{& C}_5^+ \)
  - Can be tailored to meet actual NGL compositions
  - Some prices may be difficult to obtain on a daily basis
    - NYMEX \( \text{C}_2, \text{C}_3, \text{nC}_4, \text{& C}_5^+ \) from [www.ino.com](http://www.ino.com)

- Can be expressed as \$/MMBtu (ideal gas heating value) or \$/bbl (NGL volume)
  - Make use of values for standard liquid density & heating value

- NGL frac spread requires a definition for NGL composition

Spark spread

- More important to electricity producer rather than gas processor

- Gross margin of a gas-fired power plant selling a unit of electricity having bought the fuel to produce it
Example – Propane Frac Spread

Using February values (Last):
- Propane - $0.97375 per gal
- Natural gas - $2.953 per MMBtu

Propane conversion factors:
- 91,563 Btu/gal ideal gas gross heating value & standard liquid density

Calculation:

\[
\text{Spread} = \left( 0.97375 \text{ $/gal} \right) \left( \frac{1,000,000 \text{ Btu}}{\text{MMBtu}} \right) - \left( 2.953 \text{ $/MMBtu} \right) \left( \frac{91,563 \text{ Btu}}{\text{gal}} \right)
\]

= $7.682 per MMBtu

Values retrieved January 1, 2018

Updated: January 16, 2018
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NGLs Can Bring Value

Propane & Natural Gas Spot Prices

Prices updated January 1, 2018
Sources: http://tonto.eia.doe.gov/dnav/pet/pet_pri_spt_s1_d.htm & http://www.eia.gov/dnav/ng/ng_pri_fut_s1_d.htm

Updated: January 16, 2018
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NGLs Can Bring Value

![Propane & Natural Gas Spot Prices](image)

Prices updated January 1, 2018
Sources: [tonto.eia.doe.gov/dnav/pet/pet_pri_spt_s1_d.htm](http://tonto.eia.doe.gov/dnav/pet/pet_pri_spt_s1_d.htm) & [www.eia.gov/dnav/ng/ng_pri_fut_s1_d.htm](http://www.eia.gov/dnav/ng/ng_pri_fut_s1_d.htm)

Updated: January 16, 2018
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Using February values (Last):
- Ethane - $0.25563 per gal
- Natural gas - $2.953 per MMBtu

Ethane conversion factors:
- 66,340 Btu/gal ideal gas
- Gross heating value & standard liquid density

Calculation:

\[
\text{Spread} = \left( 0.25563 \frac{\text{\$}}{\text{gal}} \right) \left( \frac{1,000,000 \text{ Btu}}{\text{MMBtu}} \right) \left( \frac{66,340 \text{ Btu}}{\text{gal}} \right) - \left( 2.953 \frac{\text{\$}}{\text{MMBtu}} \right) 
\]

\[
= 0.900 \text{ per MMBtu}
\]

\[\Rightarrow 0.06 \text{ per gal}\]

Values retrieved January 2, 2018
http://quotes.ino.com/portfolio/?id=309FD6
Gas processing as part of total production system
Total Production System

J.M. Campbell & Company
Adapted from Gas Processors Association (GPA), Tulsa, Oklahoma
Overview of Gas Plant Processing

Fundamentals of Natural Gas Processing
Summary

Natural gas supplies nearly 30% of the US’s energy
  - Contribution expected to continue to grow

Production
  - May be associated with petroleum production
  - Unconventional sources – shale & coal

Primary distribution via pipelines
  - Gas processing near the mouth of the pipeline system

NGLs bring value
  - Comparison is the value as a liquid vs the heating value as part of the natural gas
Supplemental Slides
How do energy prices compare?

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Given Price</th>
<th>Heating Value</th>
<th>Price [$/MWh]</th>
<th>Price [$/MMBtu]</th>
<th>Relative to Natural Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBOB Gasoline - wholesale</td>
<td>1.7958</td>
<td>115,000 Btu/gal</td>
<td>LHV</td>
<td>53.28</td>
<td>15.62</td>
</tr>
<tr>
<td>Heating Oil - wholesale</td>
<td>2.0681</td>
<td>130,500 Btu/gal</td>
<td>LHV</td>
<td>54.07</td>
<td>15.85</td>
</tr>
<tr>
<td>WTI Crude Oil</td>
<td>60.42</td>
<td>5.8 MMBtu/bbl</td>
<td>HHV</td>
<td>35.55</td>
<td>10.42</td>
</tr>
<tr>
<td>Brent Crude Oil</td>
<td>66.87</td>
<td>5.8 MMBtu/bbl</td>
<td>HHV</td>
<td>39.34</td>
<td>11.53</td>
</tr>
<tr>
<td>Ethanol - Chicago</td>
<td>1.4125</td>
<td>75,700 Btu/gal</td>
<td>LHV</td>
<td>63.67</td>
<td>18.66</td>
</tr>
<tr>
<td>Natural Gas - Henry Hub</td>
<td>2.95</td>
<td></td>
<td>HHV</td>
<td>10.07</td>
<td>2.95</td>
</tr>
<tr>
<td>Propane - Mt. Belvieu</td>
<td>0.97375</td>
<td>90,905 Btu/gal</td>
<td>HHV</td>
<td>36.55</td>
<td>10.71</td>
</tr>
<tr>
<td>Powder River Basin Coal (low sulfur)</td>
<td>12.10</td>
<td>8.800 Btu/lb</td>
<td>HHV</td>
<td>2.35</td>
<td>0.69</td>
</tr>
<tr>
<td>Illinois Basin (high sulfur)</td>
<td>32.60</td>
<td>11,800 Btu/lb</td>
<td>HHV</td>
<td>4.71</td>
<td>1.38</td>
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<tr>
<td>Electricity (Residential, winter season)</td>
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<td>C per kWh</td>
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<td>54.61</td>
<td>16.00</td>
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<tr>
<td>Electricity (Residential, summer, over 500 kWh)</td>
<td>9.902</td>
<td>C per kWh</td>
<td></td>
<td>99.02</td>
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</tr>
<tr>
<td>Electricity (Small Commercial, winter season)</td>
<td>4.256</td>
<td>C per kWh</td>
<td></td>
<td>42.56</td>
<td>12.47</td>
</tr>
<tr>
<td>Electricity (Small Commercial, summer season)</td>
<td>8.512</td>
<td>C per kWh</td>
<td></td>
<td>85.12</td>
<td>24.95</td>
</tr>
<tr>
<td>Hydrogen dispensed cost</td>
<td>4.03</td>
<td>324.2 Btu/scf</td>
<td>HHV</td>
<td>102.20</td>
<td>29.95</td>
</tr>
</tbody>
</table>

References:
Gasoline, Heating Oil, Crude Oil, Natural Gas from Bloomberg (1/1/2018, Feb & Mar delivery)
http://www.bloomberg.com/energy/

Propane & Ethanol prices from NYMEX (1/1/2018, Feb & Mar delivery)
http://quotes.in.com/exchanges/category.html?ceenergy

Coal from US EIA Coal News & Markets (week ending 12/22/17).
http://www.cia.gov/coal/news_markets/

Xcel Energy electric tariff book (retrieved 1/1/2018, as of 12/8/2016)

Hydrogen cost from DOE report, DOE Hydrogen & Fuel Cells Program Record, Sept. 24, 2012