RBAC's 2017 North American NGL Market Forecast

Robert Brooks, PhD, RBAC, Inc, rebrooks@rbac.com

2017 USAEE Annual Conference, Houston, Texas
November 14, 2017
Presentation
Outline

Introduction
Basics about NGLs
Modeling the NGL market
  – Basic concepts
  – Challenges
  – Data & Calibration
Market forecast 2017
About this presentation

• NGL-NA™ is a model of the North American market for *natural gas liquids*. NGLs are hydrocarbons produced with and then separated from natural gas.

• It enables analysts to study evolving patterns of supply, demand, and price in this complex market.

• It also allows them to estimate the impact of new infrastructure projects proposed to resolve market imbalances resulting from rapid NGL supply growth.

• This presentation extends those given at INFORMS 2013, 2014, and 2016 to include solutions to issues encountered in modeling this complex and extremely interesting market.
How are low oil and gas prices affecting the NGL market?

• It used to be so easy! but …

• Old relationships between NGL commodities and oil and gas prices don’t work as they once did

• Greatly expanded production has converted the US into an exporting powerhouse but just like oil and LNG, overseas NGL prices have fallen

• How will this affect exports?

• How will this affect local prices and demand?

• How should we model the North American NGL market in such a low oil and gas price environment?
Presentation Outline

Introduction
Basics about NGLs
Modeling the NGL market
  – Basic concepts
  – Challenges
  – Data & Calibration
Market forecast 2017
First – some basics about the North American NGL market

- What are NGLs?
- Where are they found?
- How are they separated from natural gas?
- How do NGLs get produced and delivered to market?
# NGLs: what are they? and how are they used?

<table>
<thead>
<tr>
<th>Natural Gas Liquid</th>
<th>Chemical Formula</th>
<th>Applications</th>
<th>End Use Products</th>
<th>Primary Sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethane</td>
<td>C₂H₆</td>
<td>Ethylene for plastics production; petrochemical feedstock</td>
<td>Plastic bags; plastics; anti-freeze; detergent</td>
<td>Industrial</td>
</tr>
<tr>
<td>Propane</td>
<td>C₃H₈</td>
<td>Residential and commercial heating; cooking fuel; petrochemical feedstock</td>
<td>Home heating; small stoves and barbeques; LPG</td>
<td>Industrial, Residential, Commercial</td>
</tr>
<tr>
<td>Butane</td>
<td>C₄H₁₀</td>
<td>Petrochemical feedstock; blending with propane or gasoline</td>
<td>Synthetic rubber for tires; LPG; lighter fuel</td>
<td>Industrial, Transportation</td>
</tr>
<tr>
<td>Isobutane</td>
<td>C₄H₁₀</td>
<td>Refinery feedstock; petrochemical feedstock</td>
<td>Alkylate for gasoline; aerosols; refrigerant</td>
<td>Industrial</td>
</tr>
<tr>
<td>Pentane</td>
<td>C₅H₁₂</td>
<td>Natural gasoline; blowing agent for polystyrene foam</td>
<td>Gasoline; polystyrene; solvent</td>
<td>Transportation</td>
</tr>
<tr>
<td>Pentanes Plus⁴*</td>
<td>Mix of C₅H₁₂ and heavier</td>
<td>Blending with vehicle fuel; exported for bitumen production in oil sands</td>
<td>Gasoline; ethanol blends; oil sands production</td>
<td>Transportation</td>
</tr>
</tbody>
</table>

*C indicates carbon, H indicates hydrogen; Ethane contains two carbon atoms and six hydrogen atoms.  
*Pentanes plus is also known as “natural gasoline.” Contains pentane and heavier hydrocarbons.
Where are NGL’s found?

Source: NPC Paper #1-13 "Natural Gas Liquids (NGLs), 15Sep11"
How are NGL’s separated from gas?

Figure 1. Generalized Natural Gas Processing Schematic

- **Gas Reservoir**
- **Gas-Oil Separator**
- **Condensate Separator**
- **Dehydrate**
- **Remove Contaminants**
- **Nitrogen Extraction**
- **DeMethanizer**
- **Fractionator**

*Optional Step, depending upon the source and type of gas stream.
*Source: Energy Information Administration, Office of Oil and Gas, Natural Gas Division.
How do NGLs get produced and delivered to market?

- Natural Gas Production
  - Wet Gas
    - Gas Processing
      - NGL Mix
        - Fractionation
          - Ethane
          - Propane
          - N-Butane
          - Iso-butane
          - Pentanes+
        - Residue Gas
          - Dry Gas
            - Nat Gas Markets
              - Non-Petchem Propane Markets
              - Other Butane Markets
              - Diluent Market
              - Export Markets
              - Petchem Feedstock Market
              - Gasoline Blending Market
Presentation Outline

Introduction
Basics about NGLs
Modeling the NGL market
  – Basic concepts
  – Challenges
  – Data & Calibration
Market forecast 2017
How should we model this market?

• Basic Design Principles
  – Multi-commodity flow model with transformation
    • Natural gas -> dry gas + NGL mix
    • NGL mix -> C2, C3, Iso-C4, Normal C4, C5+
  – High level of granularity in supply, demand, and infrastructure
  – Optimization used to compute economically efficient production, transportation, consumption, exports

• NGL market highly coupled to other markets
  – Natural gas
  – Crude oil refining
  – Petrochemicals
How do we solve it?

• NGL-NA is a highly granular, multi-period, large-scale non-linear model of the North American NGL market
• To be practical a model must solve relatively quickly
• Large non-linear models solve very slowly, if at all
• Linear optimization models can be solved in workable times by modern codes, even when VERY large
• Thus trying to linearize NGL-NA is a really good idea
Presentation
Outline

Introduction
Basics about NGLs
Modeling the NGL market
  – Basic concepts
  – Challenges
  – Data & Calibration
Market forecast 2017
Challenges

• Non-linear objective function
  – Maximize the sum of consumer and producer surplus, a non-linear function

• Multiple commodities
  – NGL mix compositions
  – Separation into “purity products”: C_2, C_3, etc.

• Problem size
  – Multi-year monthly run is too big to solve as one problem

• Capacity expansion
  – Growing supply requires new processing and transportation infrastructure

• For a detailed description of the solution, see the Appendix
Presentation Outline

Introduction
Basics about NGLs
Modeling the NGL market
  – Basic concepts
  – Challenges
  – Data & Calibration
Market forecast 2017
Data Sources

• US Energy Information Administration
  – Natural Gas: marketed production, gas processed, shrinkage, plant fuel, liquids extracted (by state)
  – NGL/LPG: production, storage, imports, exports, movements (by PADD), EIA-757: Gas processing plant data, refinery inputs and production

• Federal Energy Regulatory Commission
  – NGL pipeline tariffs

• Statistics Canada
  – Canadian natural gas and NGL supply and demand data

• Canadian Energy Research Institute (CERI)
  – Canadian NGL industry operations and infrastructure

• PEMEX / SENER
  – Mexican natural gas and NGL supply, demand and infrastructure

• LPG Almanac (Sulpetro)
  – Processing plant, fractionator, refinery, and terminal location info, capacity, storage, and production history (US/Canada)

• Energy Company Websites
Calibration Challenges

• Natural gas production and processing data is available by state
• Canadian data is available for each province
• Mexican data is available by region
• But EIA delivers NGL data by *PADD* (too aggregate)
• Calibration challenge #1 is to rationally disaggregate this data down to each state
• Challenge #2 is to define compositions which reproduce agency-reported production
RBAC has developed an NGL-NA data management system
It gathers data from EIA, Stat Canada, and SENER (Mexico)
It then loads the data into historical data tables in NGL-NA
NGL-NA’s calibration process uses these data to update
  – Supply area compositions
  – NGL content (‘wetness factors’)
  – Fractional split between “dry” and “wet” gas in each area
    • “Wet” gas contains NGL’s which are extracted at gas processing plants
    • “Dry” gas can be delivered directly to pipelines
Calibration is an iterative process
  – The user controls the number of iterations
  – Parameters are adjusted to match the historical data
  – Results are stored in output tables for post-calibration analysis
Presentation Outline

Introduction
Basics about NGLs
Modeling the NGL market
  – Basic concepts
  – Challenges
  – Data & Calibration

Market forecast 2017
Market Forecast 2017

• Assumptions
  – Natural gas supply from GPCM
  – Demand for NGL products
    • Petchem demand functions computed using
      – Existing + under const + approved @ 90% cap
    • Non-petchem propane declining slowly
    • Refinery demand stable
  – New and proposed infrastructure + hypothetical plants/pipelines for new and expanding plays
    • Marcellus, Utica, Eagle Ford, Bakken, Niobrara, Montney, Duvernay, and Permian
  – Export levels based on contracts, capacities, and competition with local markets
Natural gas production

Natural Gas Production by Country (mmcfd)

- 17Q3base CAN Mkt Prd
- 17Q3base MEX Mkt Prd
- 17Q3base USA Mkt Prd

© 2017 RBAC Inc. All Rights Reserved.
NGL production (gas processing)
“Futureplant” GPP use

GPP Future Plant Utilization (mmcf/d)

- Bakken Futureplant
- Duvernay Futureplant
- Eagleford Futureplant
- Marcellus Futureplant
- Montney Futureplant
- Niobrara Futureplant
- Permian Futureplant
- Woodford Futureplant OK CRY Use

© 2017 RBAC Inc. All Rights Reserved.
US Propane Deliveries

Propane Deliveries (BBL/Day)

© 2017 RBAC Inc. All Rights Reserved.
Petchem plant capacity utilization

PetroChem Output Utilization by Country Annual

17Q3base ETHE

© 2017 RBAC Inc. All Rights Reserved.
Exports
Price forecast
Thank you!

Questions?
Contact Information

Robert Brooks, Ph.D., Founder
rebrooks@rbac.com

Contact Numbers

Administration (281) 506-0588
Contracts and Sales (281) 506-0588 ext. 126
Direct (281) 506-0588 ext. 124

More information: http://www.rbac.com
Appendix: Modeling challenges & solutions

1. Non-linear objective function
   - Maximize the sum of consumer and producer surplus, a non-linear function

2. Multiple commodities
   - NGL mix compositions
   - Separation into “purity products”: C₂, C₃, etc.

3. Problem size
   - Multi-year monthly run is too big to solve as one problem

4. Capacity expansion
   - Growing supply requires new processing and transportation infrastructure
NGL-NA non-linearity issue #1
Non-linear objective functions

• What to do with market clearing models where the objective function has non-linear terms?

• Integrals of price-dependent supply and/or demand curves over the price domain: shaded areas in figure to right
NGL-NA’s Solution

• Solution:
  – Step function approximations for supply/demand curves
  – Objective function becomes linear
  – Clean separation of primal and dual variables
  – Solvable using fast primal-dual simplex algorithm

- The width of each vertical segment is the incremental demand available if and when the price decreases to the next level.
- The total demand available at price $p_4$ is $q_0 + q_1 + q_2 + q_3 + q_4$.
- As price decreases, total demand increases at an increasing rate until it approaches a maximum “saturation” demand level.
NGL-NA non-linearity issue #2
NGL composition and mixing

• Natural gas supply has different compositions in each area and play AND gas processing plants produce NGL mixes with different compositions

• Combining NGL mixes results in new compositions which depend on the volumes mixed, resulting in a non-linear model in the constraint set (very bad)
  – Frac $C_2^{AB} = (Q^A \times \text{Frac } C_2^A + Q^B \times \text{Frac } C_2^B) / (Q^A + Q^B)$

• The fraction of $C_2$ in the mix AB is a non-linear combination of its fraction in mixes A and B and the flow variables $Q^A$ and $Q^B$

• Mixture compositions are non-linearly flow dependent
NGL-NA’s solution

• Compute *supply compositions* as the fractions of NGL components (C2, C3, N-C4, I-C4, C5+) in the gas supply *before it is processed*, based on industry reports of gas composition in different regions and plays

• Specify a set of processing efficiencies for each type of gas processing plant and operating mode

• Combine these two to define *NGL compositions*, the set of compositions *after the NGL has been processed*

• Each *NGL combination* defining a unique type of *NGL Mix* is modeled as a separate commodity

• Each unique MIX is tracked throughout its journey from processing to fractionation to delivery to market
NGL-NA issue #3: Model problem size

- NGL-NA is an extremely granular model
  - ~ 140 natural gas production areas
  - ~ 1,000 gas processing plants
  - ~ 50 fractionators
  - ~ 150 refineries
  - ~ 60 petrochemical plants
  - ~ 500 storage and distribution terminals
  - ~ 150 pipelines plus rail, truck, and barge
  - ~ 30,000 origin-destination combinations

- It is also a multi-period model (monthly time frame)
  - 25 year scenario = 300 time periods

- Thus, it is just plain BIG and solving it over a long time horizon is not practical (both memory and solve time)
NGL-NA’s solution

• Instead of trying to solve it all at once (300 periods) …
• Use a rolling time horizon of 15-24 months
• Solve the model over this horizon, but only save results for first 12 months
• For example, for a 25 year scenario from 2016-2040 using a rolling horizon of 15 months
  – Solve Jan-2016 through Mar-2017 (save through Dec-2016)
  – …
  – Solve Jan-2040 through Dec-2040 (last year of run)
• Run times are now linear in time (number of years) and within the limits of practicality (about 1 hour per year)
NGL-NA issue #4

- Realistic scenarios with fast-growing natural gas production need **more infrastructure capacity** than exists now or has been announced in industry publications
  - Without new plants, produced wet gas could not get processed, but cannot be delivered to pipelines
  - Without new fractionators, NGL could not be converted into sellable NGL purity products
  - Without new transportation, NGL mix and purity products could not get to fractionators or markets
NGL-NA’s solution

• For each fast growing natural gas play in regions such as …
  – Appalachia (Marcellus / Utica)
  – Permian Basin (oil-associated / Alpine High)
  – Oklahoma (SCOOP / STACK)
  – Western Canada (Montney / Duvernay)

• … create a hypothetical large “Future Plant” for processing and/or fractionation
  – Also create a new pipeline to connect it to downstream markets

• Utilization of these plants in various scenarios can help quantify market need for additional infrastructure in the future